The Use of Explosives in Making Ditches

Published by
The Institute of Makers of Explosives
103 Park Avenue, New York City

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INTRODUCTORY

THIS bulletin is published by the Institute of Makers of Explosives. It is not intended to sell anything, or in any sense as a piece of sales literature, but as a manual or handbook for those who drain land and make ditches, and possibly as a textbook for students of agriculture and rural engineering.

Ever since the blasting of ditches has become standard practice there has been need of some book of reference containing the essential facts about the use of explosives in the making of ditches, eliminating untried theory and conflict of opinion so often found in less complete publications on the subject.

Sufficient knowledge and experience in the use of explosives for this purpose have been accumulated. The time has come when such a book can be prepared authoritatively.

These ditches show the result of cutting the sod and the earth along the sides before the blasting. Shovel blades, axes and a hay-knife were used. A man cut a rod along one side in about two minutes. The blast left the soil outside of the cut firm and intact, while scooping the contents of the ditch out clean. (Upper, Miller Drainage District, Marion Co., Oregon; lower, Connecticut land of Polytechnic Institute of Brooklyn.)

The Matter of Farm Drainage

Much draining of agricultural land has been neglected because it has demanded so much money, time and hard work, and so many men. The excessive cost of ditching has retarded plans to drain, and poor methods have retarded actual construction.

In times past ditches have been made largely by hand shoveling. A few of them have been plowed out when shallow ditches could be made to do the work at all. But the digging of a few hundred yards of ditch 3 feet deep has been a summer's work on a farm, and the draining of land always has been very expensive and hard.

With the increase in the cost of labor, and the scarcity of farm help compared to the numbers of men that used to be available, there is serious need for means of draining that are easier, quicker and cheaper. Since ditching with explosives has become well known and generally practiced, it has come to be the desired method.

Observe the even spreading of excavated earth over the surrounding ground, leaving little elevated bank on the edges of the ditch. Even in heavy, stiff clay such as this, the explosion grinds the earth up pretty fine. (Chester Co., Pa.)

With few exceptions, ditches can be excavated with explosives anywhere. The nub of the whole matter lies in the fact that one of the cheapest ways of moving dirt known is with explosives.

To blast ditches practically all that is necessary is to punch lines of holes and push charges to the bottom. The sides and bottoms of the blasted ditches are not as smooth as if they were shoveled out, but they are even and true, and the flow of water soon levels them down and smooths the bottoms.

The work can be done quickly, neatly and with no expensive outfit. It calls for few men. A month's work by ordinary methods can be done in a day, or a week's work in an hour. Ditches can be blasted through any kind of ground except dry sand. The presence of brush, grass, stumps and stones is no bar to this method of cutting out the ditches, though of course they dig out smoother and cheaper when the nature of the ground is clean and clear.

As for size, ditches of almost any desired depth greater than 1½ feet and any ordinary width greater than 3½ feet can be blasted out. Ditches in fields

Representative blasted ditches in sandy loam of the Atlantic Coast section. In such material the charges must be heavy and must be skillfully placed to produce the perfect results shown. With proper care the excavation is satisfactory and the sides more even and true than in clay soils.
(Charleston, S. C.)

and along roads, ponds, canals for drainage or boats, stream channels and similar cuts for any purpose can be blasted out.

This book explains the possibilities of blasting and makes clear the basis on which choice of a method for your work should rest. It shows how to plan and to lay out drainage systems, and how to construct open ditches to the best advantage. Other methods than blasting are recommended frankly when conditions and purposes are such that can be used to the best advantage.

Conditions Demanding Drainage

Two classes of farm land should be drained. One is the usual swamp land where the ground is saturated with water or at least is too wet for the growth of cultivated plants. The other class is land now cultivated, but which at some part of the year carries excess water.

The wet or damp lands may be merely low spots in fields, or may be entire valleys. Low spots often can be dried by cutting a ditch through rims of higher ground surrounding. If the wet condition is caused by overflow from streams, the stream channels should be deepened or widened till they carry all the water. If seepage from springs on the land or above it causes the trouble, a ditch cut across the flow of the seepage water will be the proper remedy. If the water-table is too high, a big open drain may gather and carry away the surplus, lowering the surface of the ground water to where it will not interfere with roots.

On account of the matter of moisture storage, as well as on account of general fertility, all land which is cultivated should be drained thoroughly of excess water. It is not enough to reduce the surplus to a point where meadow grass will grow; the drainage must be sufficient to dry off the ground soon after each rain and soon in the spring.

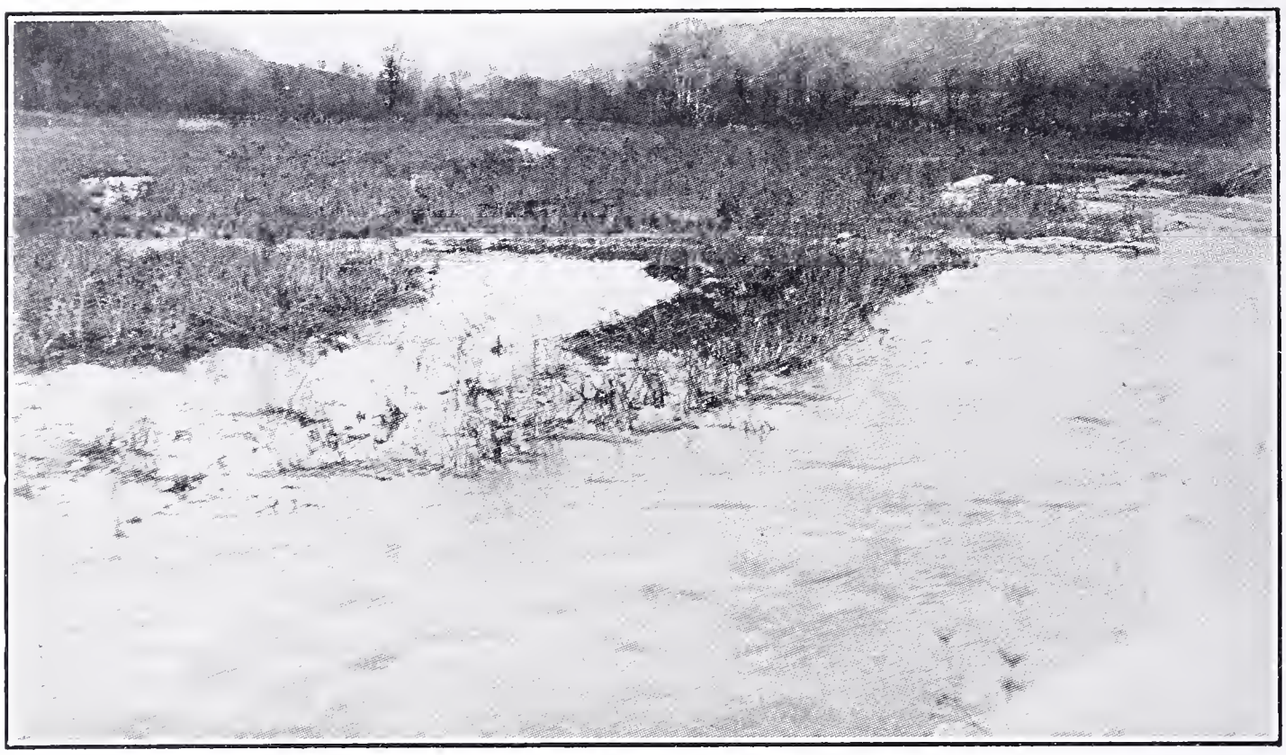
Roads always must be well drained if they are to remain solid and hold their shape in wet weather. Crooked streams should be straightened, to prevent cutting of the banks and overflowing, and ditches and streams too shallow or small to carry the volume of water present should be deepened or widened. Swamp conditions are a menace to health, breeding mosquitoes and their attending diseases. It often pays to drain lowlands where water stagnates, from the standpoint of health and comfort alone, when they are worthless for any agricultural purpose.

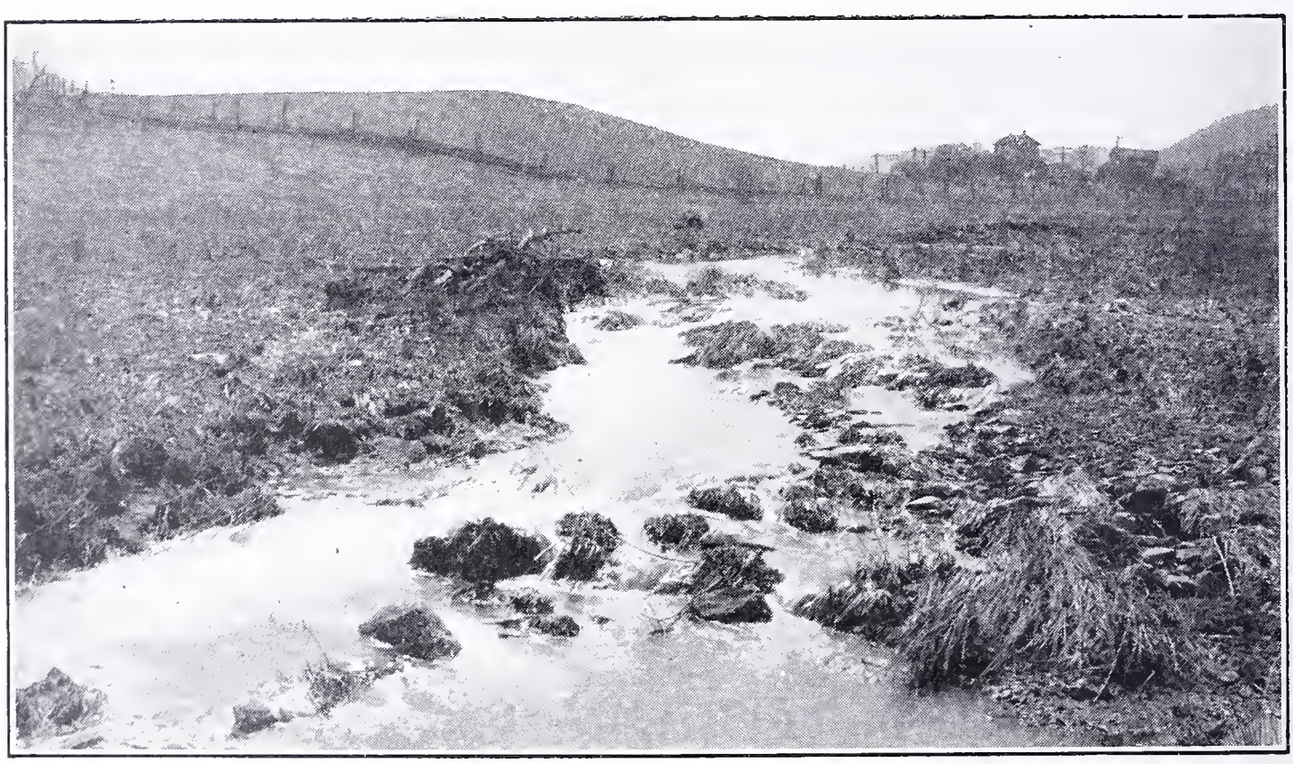
The Value of Drainage

Good drainage not only removes surplus water but actually helps to store moisture against dry weather. When soil is choked with water, deep rooting of plants or trees is impossible, and the soil processes which make available the plant food are hindered or altogether prevented. It is the absence of air almost as much as the presence of the water that does the damage. The better land is drained to a proper depth in each case, the finer and more mellow and crumbling it will be, and the more of useful moisture it will hold in the summer.

Swamp land usually is very fertile when the excess water is removed, and will grow wonderful crops. It contains a rich supply of plant food. Such land must be aerated—drained—and limed before its fertility can be used.

The direct loss of income from the idle acres in swamps can be figured by anyone. But this is not the only loss. There is the decreased net profit from other land that is farmed under the same ownership. The swamp land costs interest on its purchase price and taxes every year. This cost must be paid by the productive acres.





Two pictures that tell a story of swamp grass damming up a stream, which backs up and floods a field, ruining the hay, or corn or any other crop which may happen to be there. To dig out by hand or plow out such a clogged stream-bed is difficult and expensive, but to blast it out is the work of one man for an hour or so, at a comparatively small cost. (Mud Lick Farm, Julian, Center Co., Pa.)

Winding streams cut up and waste much land. They change their courses every year or so, tear away the banks at the curves, gouge out deep holes and build up sand bars. They occupy many times the area they would if straight, and practically ruin the soil which is worked over by the water. (Mud Lick Farm, Julian, Center Co., Pa.)

There is another feature of the matter that ordinarily is overlooked. This is the black eye which the farm is given by a ragged-looking piece of swamp land touching the clean acres. Whether the farm is on the market or is to be kept as a home, the waste lands cut down its value and damage its reputation among all who see it, including the stranger passing by, the neighbors over the fences and the man who lives on it.

It is a well-known fact that malaria disappears when mosquito bites are eliminated, and that the mosquitoes can be eliminated by draining the swamps.

The excavation done by a single line of charges of explosive properly placed in watersoaked clay soil is remarkable. The ditch resulting sometimes is two-thirds as deep as it is wide at the top. The bottom is U-shaped.

In the lowland sections of the country this has been done with great success. Even in the flat lands joining the ocean where tide water sometimes washes in over land and makes ponds, the opening out of channels has drained away the water and killed off the mosquitoes.

Other enemies that breed and lurk in swamps are weeds and predatory animals. The seed weeds in the swamps pollute all the surrounding land, and the cleaning up of the swamp is a favor and a benefit to the entire neighborhood.

Horses and cattle often get mired into the soft mud and are unable to get out without help. They may stick there and starve if not discovered and pulled out, or they may break a leg, or sprain themselves in their struggles.

One of the meanest things a farmer has to do is to haul loads of hay, grain, manure or fertilizer through a swampy place in the field. The remedy is to open a ditch through the center, after which the soft ground will harden up and the ditch can be bridged.

But not all wet land should be or can be drained. In general whether it will pay to drain or not will depend on how cheaply the job can be done, though this is such an indefinite rule that it is not of much value. Many a drainage job that can be done for $50 to $75 will add $100 to $200 to the value of a property. From a financial standpoint, a man is not justified in spending more money than the crops that can be grown will return in a reasonable number of years, though other considerations may make it wise to spend more.

The Essentials of Successful Ditching

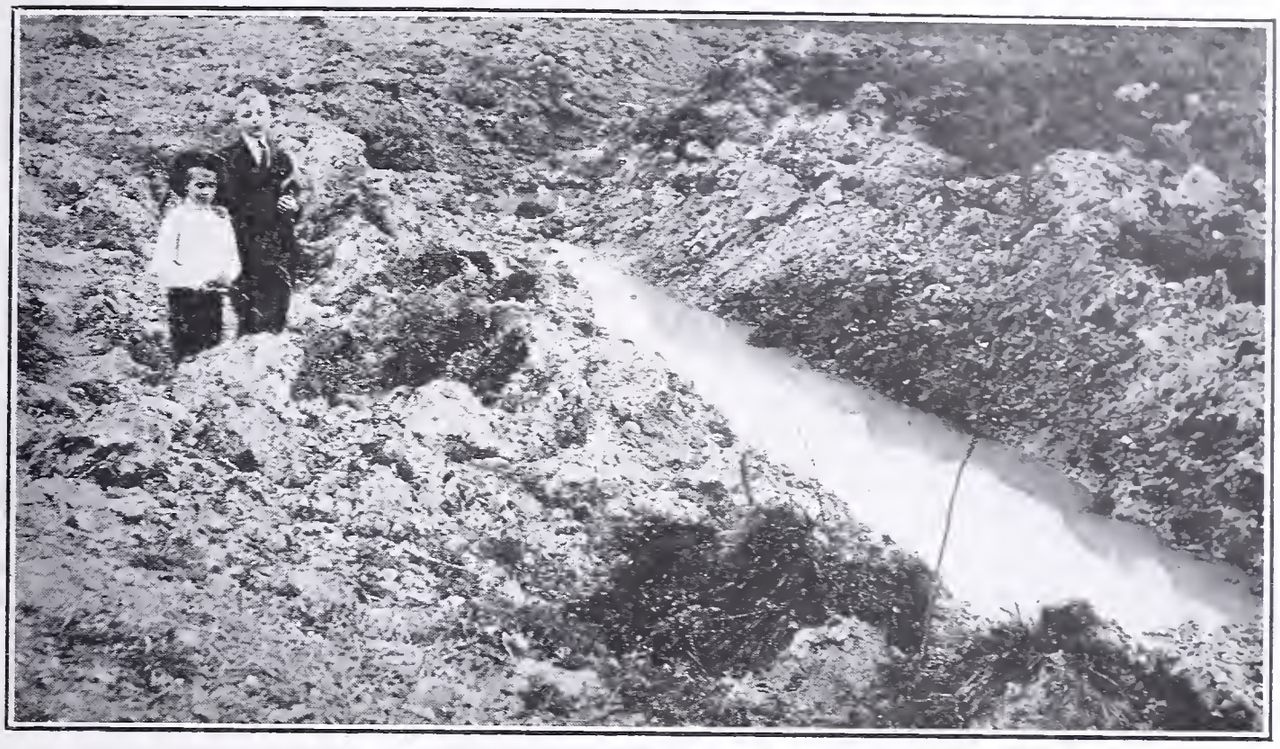
It is well to have a clear idea of what to require of a ditch before attempting to complete the plans for it.

The successful drainage ditch should be straight, to give an even, swift flow of water without cutting out the banks or filling up the bottom. Its sides and bottom should be smooth and true, both to facilitate the flow and for appearance. It must be deep enough to put the water-table at a proper level. It must be wide enough to give the capacity required by the volume of water to be carried in flood times. The grade, of course, must be enough to carry the water away and to make the drainage action sure.

The excavated material ought to be well scattered and spread evenly over the surrounding land, without leaving a ridge or dyke along the sides of the ditch. When this material is piled up along the ditch it takes up ground space and acts as a dam for surface water and compacts the subsoil beneath by its weight, making the drainage of the fields much slower. Finally,

One of the best demonstrations of the value and success of the blasting of ditches is in cutting a large channel through difficult ground for a short distance, as this picture shows. One man can do the work in a couple of hours. The expense is not to be compared to the cost of cutting the same ditch by plowing, hand shoveling or machine work.
(Valley Creek, Pa.)

the ditch in respect to cost, time and men needed for construction, must come within the available limits. The cost must be low, the time of construction short, the men required few, and the work not unreasonably hard. Frequently if the ditching is to be done at all it must be by only two or three men in what practically amounts to spare time.



The line of the ditch follows the line of the charges faithfully, making true curves and angles. It should be the policy to eliminate all twists and to make the ditch as straight as a string whenever possible. (Chester Co., Pa.)

There of course are many large agricultural, road, lumbering and other enterprises to which these remarks do not apply, because the ditching must be done and men are hired for the purpose. The managers of such propositions are fortunate in having eliminated for them one of the chief difficulties of farmers.

Ditches, canals and other such excavations not intended for drainage do not differ much in requirements from drainage projects. Cost, time and labor required always are the important considerations.

Nature of the Ground

The reasons why land is wet are few. There may be a layer of ground a few inches or a few feet under the surface, holding the water from escaping downward. The topsoil itself may be of such a nature as to prevent water from percolating through it. The water may keep rising from springs, producing the condition called seepage or spouty land. Again, the water-table, or height of the surface of a nearby large stream or lake or bay, may be nearly up to the surface of the ground, or the stream or ditch carrying away the water may be too small or too high at its mouth.

The nature of the ground must be considered in deciding on the method of ditching. Sand, for instance, is easiest to handle by some methods, and hardest by others. Dry ground handles cheapest in some ways and most expensively in others. In ditching you are likely to encounter hardpan, gravel of all sizes, both loose and in solid beds, and every kind of mixture of these materials. Each of these conditions calls for its own sort of treatment.

A ditch blasted through very dry ground without any side cutting. The result is not altogether a success, since the excavation is reduced in amount and is incomplete, and the cost is high. The soil is coarse sandy loam with much clay beneath. The blasting would have been much more successful if the ground had been full of water and the sides of the ditch cut before the blasting was done. (Near Snow Hill, Md.)

Heavy charging and skillful management will blast out a very good ditch through extremely difficult ground. Here the soil was matted with green roots. Some of them are left projecting into the ditch, but most of them are broken off and thrown out. The excavation of earth was very complete, owing to its watersoaked condition. (Georgia.)

Choosing a Method of Draining

The methods that are available for making ditches are:

Shoveling by hand,
Plowing,
Trenching with machine equipped for excavating,
Blasting.

Each method has its place. In choosing a method many considerations enter into a wise decision. The purpose for which the ditch is made—whether open ditch or underdrain, canal for water or boats, and the like, must determine the character of the ditch. The kind of soil, the size of the ditch, the amount

Note the projecting knobs of earth held by matted roots of trees and brush. Such irregularities in the sides of a ditch are not a disadvantage except in appearance in a ditch where the flow of water is heavy and swift. But when the volume of water is small and the fall slight the edges should be smooth and straight.

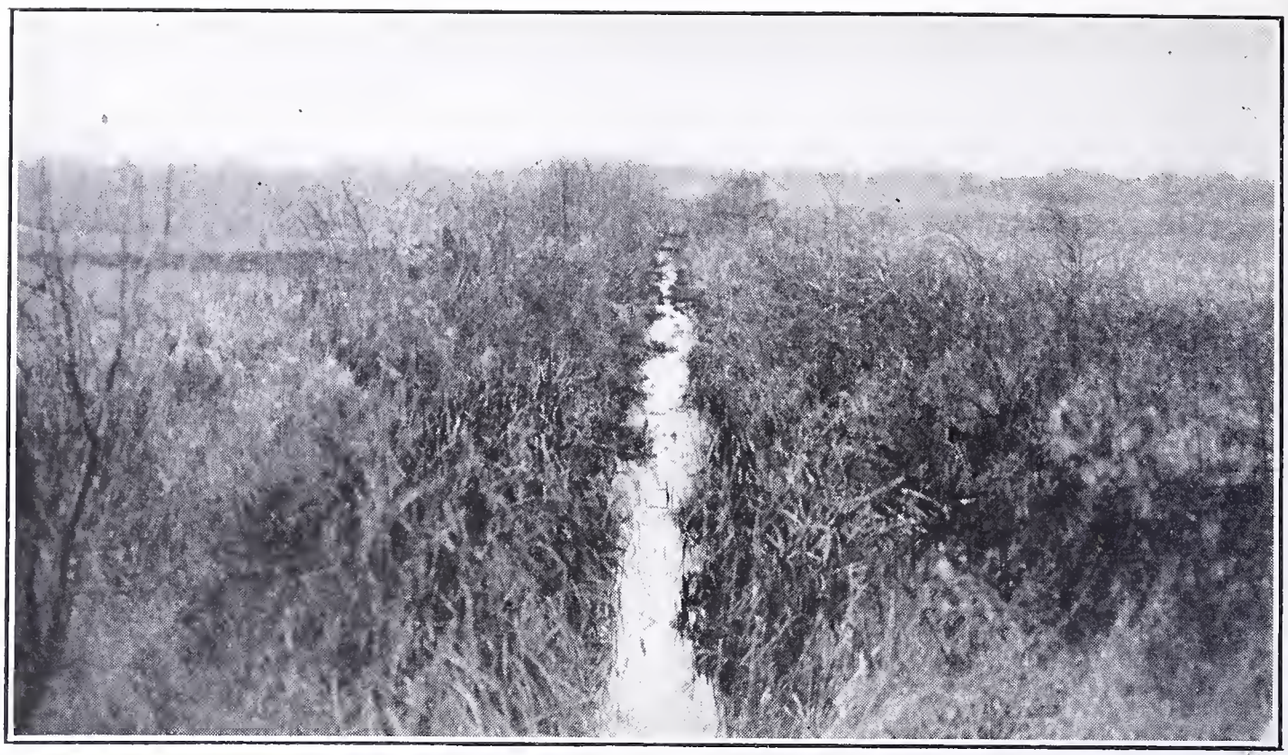
and kind of obstructions, the time available before the job must be finished, the men that can be put on the job, the capital available for labor and equipment, the source of the water to be drained away, the height of the water-table, the use of the land to be drained, the amount of water to be carried and the fall of the land —all these factors have a bearing on the selection of the method of making a ditch.

Tile Drains

No open ditch through cultivated land should be considered when conditions are such as to make underdrains better, and when money is available for constructing them.

But in a great many places the nature of the ground or water flow is such as to require open ditches. In other places they are just as good as closed drains. For instance, through pasture land and woods an open ditch will do just as well as an underdrain and better where there is a spring or brook which overflows at times. In muck land closed drains are not practicable.

Ditches for immediate laying of tile cannot be blasted out with satisfaction; the bottoms are left too soft to hold the pipe properly. If funds for tile draining are not available immediately, an open ditch can be made by blasting which, after a couple of years, will be entirely satisfactory for tiling, though



Proper blasting will open a channel through thick brush and grass, though such a ditch will not measure nearly so much in the clear as though the land was clean and free from roots. You can blast channels for boats or for drainage through a marsh where the ground is under water. (Kentucky.)

the earth required to refill the ditch will be scattered widely. Light blasting very often is desirable, however, to loosen hard ground in order to make digging of tile ditches by other methods easier.

Open Ditches

Large ditches and canals, 15 feet wide or more, and miles in length, often justify the use of a floating dredge. Those who are interested in methods of trenching for underdrains, and in excavating machinery, floating dredges, ditching plows and the like, should get Farmers' Bulletin 698 of the U. S. Department of Agriculture. It goes into the subject in detail.

An entirely successful ditch blasted through heavy, thick muck. Note that the watertable is very near the surface of the ground. The soil is not thin enough to cave in or float into the excavation, hence the blasting is at its best. (In Howachitto Swamps, Adams Co., Miss.)

What can be done by blasting in sand. This big ditch was made with explosives near Pinellas, Florida. The conditions are about the most unfavorable under which it is possible to blast out ditches. Heavy charging and electric firing were required here.

When many stones, roots and stumps are present, a dredge, or in fact any excavating machinery, cannot be used to advantage or at all. Ditches less than 2 feet deep can be plowed out cheaply, using two or four horses hitched by means of a chain to a plow of some kind. Another implement that is effective for making very shallow ditches is a scraper, either with or without wheels. A road machine or scraper is about as good as any. The trouble with them is that they will work little more than to a depth of a foot. They also are expensive. Their advantages are that they scrape the dirt well back from the edge of the ditches and make an even, clean-looking job by machinery instead of by hand.

When tile is to be laid in hand-dug trenches, begin the spade work in the bottom of a plow furrow. By running the plow twice in the same place you can make the furrow nearly 12 inches deep.

Blasting of ditches is discussed under a separate heading.

Possibilities and Limits of Blasting

The blasting method can be used for making almost any open ditches A blasted ditch made with one line of charges usually is about twice as wide

Blasting makes the cleanest and smoothest job in sandy loam that is saturated with water nearly to the surface. Note how cleanly the edges of this ditch are cut. Also note that no excavated earth was thrown to the right of the ditch, in the picture. A strong wind carried it all over to the left side.

at the top as it is deep. The sides and bottom are fairly even. The dirt is spread out widely without leaving ridges down the sides. Ditches can be blasted successfully in clay, loams, gravel, thick muck, peat, and, in fact, every sort of earth except very thin muck and dry sand. Ditches can be blasted through sand when saturated with water.

It is easier to state the limitations of the blasting method than its possibilities. As stated above, you cannot blast ditches through dry sand. Thin muck runs into the excavated channels. In any ground where there are many roots of trees or brush, the sides of the blasted ditch will be ragged unless the roots are cut beforehand along the sides. In blasting through heavy sod, the sod sometimes folds back without tearing loose, or else simply flops back down into the ditch—unless the edges are cut before the blast.

These are the limitations of blasting, and there is a way to overcome each of them except that of thin muck. The fact is that the way explosives will cut out a narrow channel is really wonderful. Those who have not seen the blasting of a ditch can have no idea of the efficiency of the work of explosives for this purpose or of the clean and finished job they do.

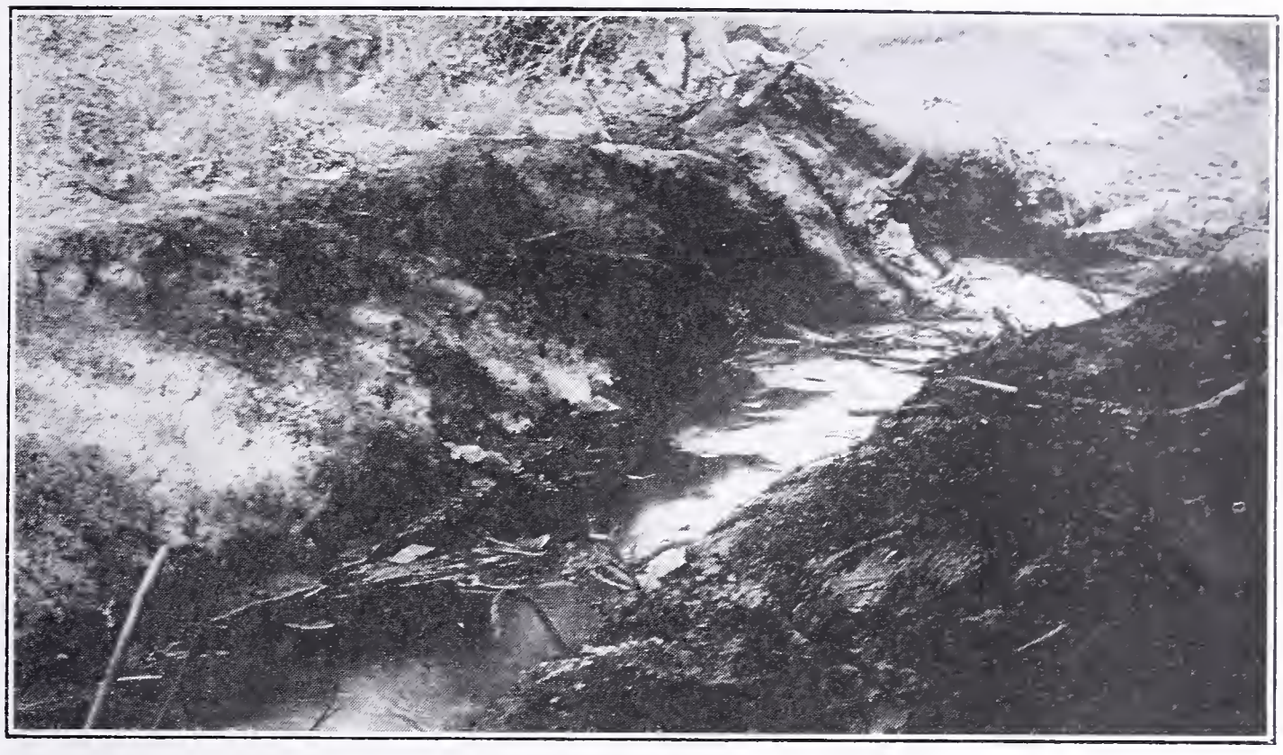
Explosives work to the best advantage when the ground is wet—in fact in thin mud. It takes less explosive to throw out a required sized ditch, or the same amount of explosive will make a bigger ditch, when the ground is thoroughly

A big ditch blasted through a swamp where the muck was almost too thin. The sides of the ditch moved in a little, but stopped as the water left them and they dried a little. Blasting is very effective in muck, so long as the material is not so thin that it moves in and closes the excavation later. (Gilliard's Lake outlet to Mississippi River, through Howachitto Swamp, Adams Co., Miss.)

wet than when it is only damp or is dry. The blasting may be done with perfect satisfaction through ground that is so soft that there is no footing for horses and no support for wheels. In fact, it can be done when the surface of the ground is under water.

Excessively soft ground, stones, stumps and roots are the things that make ditching by hand or by machinery costly and difficult, if not impossible. But they interfere with blasting very little and raise the cost only slightly. Blasting of ditches can be done in dry ground of a heavy nature. The general rule is that the wetter the soil, down to the thin muck stage, the better and cheaper the blasted ditch.

The cost of digging by hand in connection with plowing and scraping, in any ditches more than 2 feet deep, is upwards of 25 cents per cubic yard, on a basis of $1.50 per day labor. The cost of blasting will range from 6 to 16 cents per cubic yard, depending on the nature of the soil, its condition at the time and the skill of the blaster. This comparison in itself is enough to demonstrate the efficiency of the blasting method.



It is possible to blast out a good ditch through almost pure sand, as this ditch shows, provided the ground is full of water and the operator understands his business well.

About the smallest ditch it is worth while to blast is 1½ feet deep and 3½ feet wide. From this size up to 6 or 8 feet deep and 18 or more feet wide the use of explosives has advantages over almost any other method under favorable conditions. But in general the efficiency of the blasting method falls off after the depth is greater than 6 feet and the width greater than 18 feet. For long ditches a floating dredge will be economical. Small ponds may be dug by blasting.

In blasting ditches two or three men can do the work of a great many. They can accomplish in a day or two what would take them months to do by hand.

Laying Out the Ditch

The size or capacity of ditch required, the grades, the depth and the lines should receive careful attention. When there is considerable length of ditch or considerable acreage to be drained it is wise to employ a drainage engineer or a professional surveyor in getting the grades and in determining capacity. Except in very large operations the matter of depth and location of the lines of drains is largely one for farmers themselves to decide, because they know the requirements of the different soils and of farm operations, as well as have had the chance of observing the flow of flood water.

The eye is not to be depended on in determining the fall of a piece of land that is nearly flat. Use a level. One way of using it is to drive a post at the upper side and fasten to this, by nailing or bolting, a crosspiece with a straight edge up. Then lay a level on the straight edge and make it absolutely level. The crosspiece should point directly toward the lower side of the piece of land

In big drainage projects where large canals must be made the blasting method often proves economical. There is no doubt that explosives will do the excavating, as this picture shows. Labor cost and complications are reduced to a minimum on account of the few men and short time required for the blasting.

to be drained, where a helper must stand, holding a marker which he raises or lowers on a pole. Sight over the straight edge and have him elevate the marker till it is on a true level with your crosspiece. The difference between your distance down to normal ground surface or normal water surface, and his, will be the fall.

An "A" frame or any other support for the level will do if it will hold the level steady. For about 60 cents, sights for attaching to the level can be bought of almost any hardware store. Ask for Stanley level sights. They are as accurate as rifle sights. Tripods for holding the level also are made by the Stanley

This ditch is a good instance of the speed and efficiency of the blasting of ditches. Three men made it complete, as the picture shows—1000 feet long—in 5 days. About 400 pounds of explosive was used. Much cutting of roots and sod was required. (The Hart E. Hutchens Co., New Britain, Conn.)

firm and cost about $2.50 at most hardware stores. The plain level is not very accurate. If you do not use sights, repeat the sighting two or three times to make certain of the finding.

Another reliable way of getting a grade is to use water in a hose. Use a length of 20 to 50 feet of hose. Turn up the ends for 6 or 8 inches and tie them up. It is well to insert in these ends, tubes of glass, like the water-gauge glass of steam engines. Fill the hose with water and lay it on the ground or in bottom of ditch. The height of water in the ends will show the level. You can use this device round bends in a ditch.

A fall of one inch to each hundred feet is enough to carry off excess water from a field in most cases. This is for straight ditches. If the ditch line is to swing here and there, an inch of fall is hardly a sufficient allowance.

Part of a half mile of ditch blasted out complete, with no work in preparation or finishing ground. The ground was full of water, and transmitted detonation was made use of to fire the charges in about 200-foot sections. Note that the line of the ditch is true, the edges fairly even and smooth, and the earth well scattered.

Grade, Fall and Line of Ditch

The appearance of grade is deceiving. Few pieces of ground are so flat they cannot be drained. Watch the land when it is flooded and the water is going down. Set some stakes then to indicate its level and its channels. If a small stream flows through the land, the line of sight should not follow its wandering course. The total fall should be determined from just two positions—one where the stream enters and one where it leaves.

The flow of the flood water is a good guide in locating the proper line for a ditch. This is the natural line of drainage. If nothing else interferes, place the ditch in this position. The idea is to have it near as possible to a straight line and as short as possible. But avoid cutting fields with open ditches when possible.

Determining Ditch Depth

The one important factor to consider in determining how deep a ditch should be is the proper height of the water-table in the ground. This is the level of the water that will stand in a well or hole dug in the wettest part of the field. The water should be at least 4 or 5 feet below the surface in ordinary heavy loam or clay, and 1 to 1½ feet in muck.

The deeper a ditch is the farther and more thoroughly it will drain land. Your calculations as to how far you can rely on one ditch to gather water and to effect the drainage of ground must be based on this matter of the depth of the ditch. The nature of the ground has a good deal to do with it, particularly with the rapidity of the drainage. A loose, open gravel will drain out nicely in a few days, and a tight stiff clay will take

The first shot (of 12 charges) of a ditching operation. Note particularly how abrupt and clean-cut the end is. The last charge lifted its load fully and cleaned out the ditch in good shape. The next one placed beyond will continue the excavation just as well. (Mud Lick Farm, Julian, Center Co., Pa.)

weeks. Naturally the ditches should be closer together in the clay than in the gravel. Other soils can be judged from these.

The depth must not be more than the water-level at the mouth of the ditch or drain. This is a governing factor in many places. When a ditch empties in a stream you often can carry the channel farther down and secure a lower level if it is needed; or the stream itself may be deepened.

The water carrying capacity of a ditch is most largely governed by its width. Often the narrowest ditch that can be made will have more capacity than is needed to carry all the water there is. The bottom should not be wide, but should be narrow, almost like a broad V, because the amount of water to be carried at low water stage is small and it should be confined closer to make it flow better. In flood times the water will rise higher and will make a broader stream.

Determining Width of Ditch

This ditch is 5 feet wide and 3 feet deep. It was blasted out with one row of charges placed 18 inches apart, each charge consisting of one stick of powder. About 100 feet of the ditch was excavated at each explosion.

Where large swamps are to be drained, or the flow from larger springs is to be carried away, a ditch of minimum width sometimes is not big

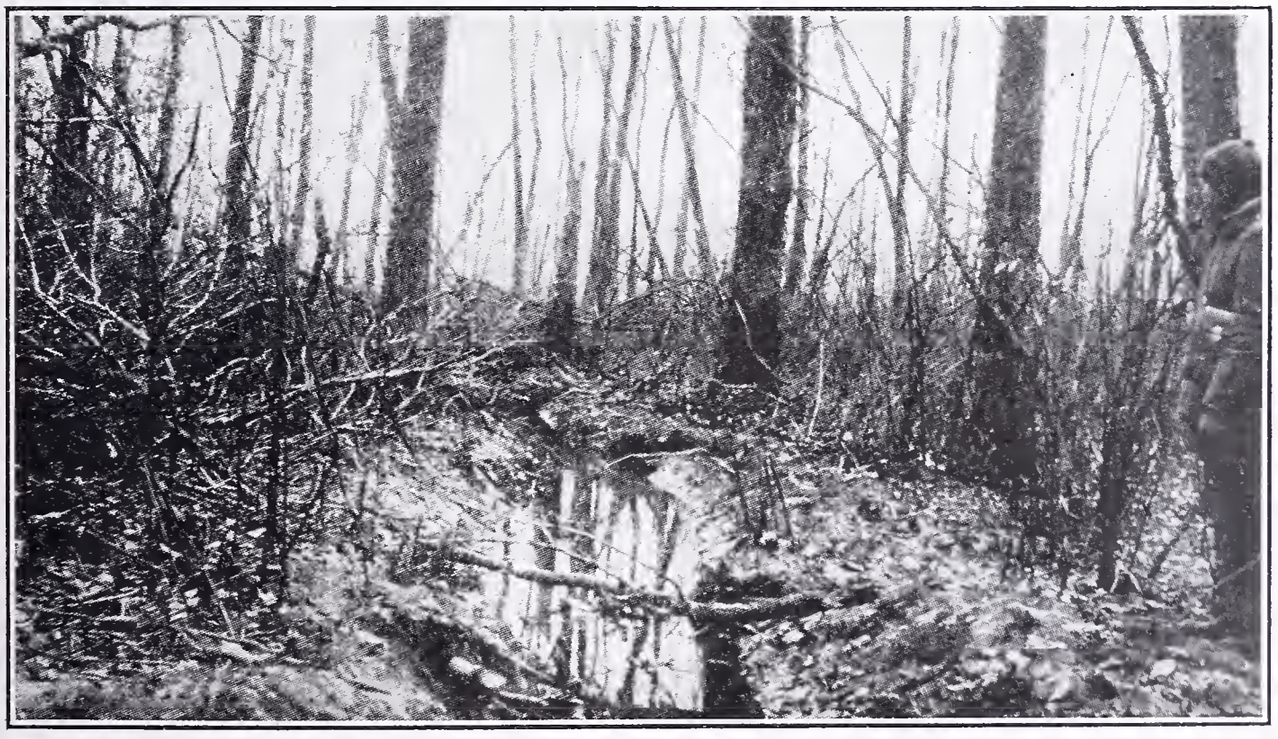
enough. If you can calculate the volume of water to be carried away, you then can figure the correct width for your ditch. Measure the flow per minute in cubic feet at some outlet. Or measure the amount of standing water by getting its depth and extent. Provide ditch enough to pass the volume present in the required time. In any case the ditch should be big enough to clear away the water of a 2 or 3 days' rain shortly after it stops coming down, and to take care of spring floods.

How to Make Ditches by Blasting

Description of Blasted Ditch

Ditches are blasted by loading suitable charges in holes made in a row or line. Each charge of explosive properly placed for ditch blasting will blow out, roughly stated, a crater which is half to three-quarters as deep as it is wide. Nearly all the dirt is thrown out. Most of it is lifted to a height of about 200 feet in the air, requiring some seconds before it returns to the ground.

The sides and bottom of blasted ditches have 6 to 12 inches of loose dirt, which can be left where it is if the ditch is big enough in the clear, or can be taken out easily and cheaply by shoveling or



In these ditches the excavation of earth was satisfactory, but the number of roots was so great that the result as a whole is not what it should be. No side-cutting was done before blasting. If there had been, the resulting ditch would have been smooth, straight and deep. In blasting through brush and timber, the long, sharp shovel blade, the hay-knife and the axe are necessary tools. (S. Chester Coursey, Hayden, Md.)

with light horse scrapers if a larger ditch is wanted. Good blasting practice will so load the charges that the ditch as cleaned out by the blast will be big enough in the clear and will require very little, if any, hand finishing.

Firing Charges

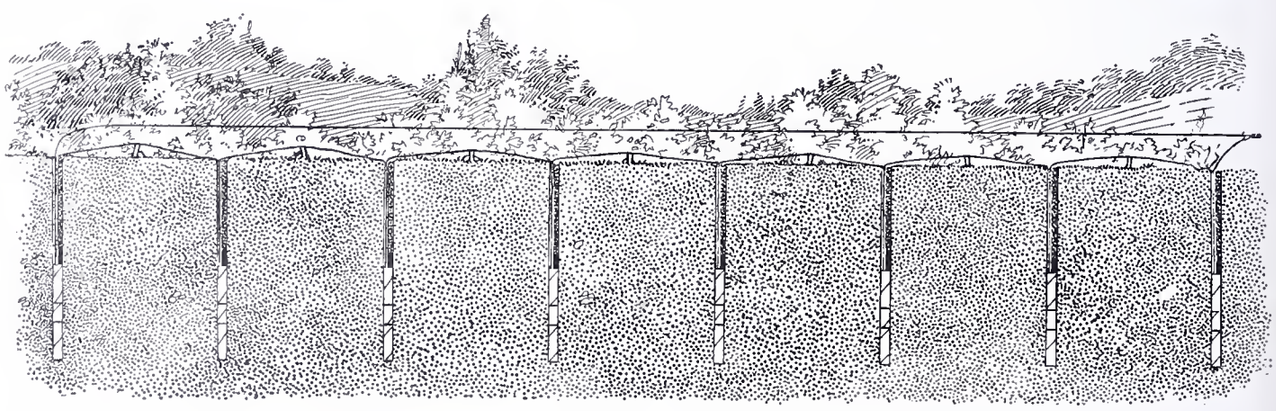
One of the first things that must be considered when planning to make a ditch by blasting is the method of firing the charges of explosive. Most of the rest of the operation hinges on the firing so much that this matter must be determined before even buying the explosive.

The standard practice is to fire all charges electrically, as will be described immediately following. This method is sure in results under any conditions. Ordinary cap-and-fuse firing cannot be used successfully in ditching, except by the transmitted detonation method in which the center charge only is set off by a cap, the rest being fired by shock transmitted through the ground. This method is fully explained on pages 22 to 25.

General Method of Firing

Ditches can be blasted through any sort of ground except dry sand when the charges are fired in this way. The procedure is as follows:

The charges are prepared for loading, with electric blasting caps, in the manner described on pages 34 to 38. Prime each charge. Holes are made in the ground on the ditch line and the charges are loaded as described in following pages.



Typical loading of ditch blast for straight electrical firing of all charges for 3½′ x 7′ ditch.

The holes or charges should be spaced 30 to 40 inches, and where very heavy charges are used, as much as 50 or 60 inches apart. They must be close enough together so that all the earth between each two will be thrown out clean, leaving no ridges in the bottom of ditch. Thirty inches ought to be close enough under any conditions of soil and size of charge. The only way of determining definitely just how far apart the charges should be is to make test shots, as suggested on page 31, in the discussion of amount of explosive required for charges. As many charges should be loaded as your electric current can fire.

The actual firing is done by connecting the wires of all the charges and sending an electric current through them. An electric blasting machine should be used to supply current, though power or light current can be used. A full discussion of the details of how to connect wires and to fire, is contained in the special chapter on the subject in the latter part of this bulletin.

You can fire as many charges as your blasting machine will handle. The machines are made in different sizes, to fire 3 to 150 charges at once. Procure a large machine if you have miles of ditch to blast, but if you have only a few hundred yards, a 30-charge machine is big enough.

The proper explosive for blasting ditches by this method depends somewhat on the soil. In all clay and heavy soils use 20% ammonia powder or dynamite, and for large ditches use 30% or 40% ammonia powder or dynamite except when the work is under water. (See page 46.) In blasting ditches in wet sand or other light ground use 50% nitroglycerin dynamite or powder. Where charges must remain under water more than half an hour, use nitroglycerin explosives only, for ammonia explosives will deteriorate if soaked for excessive periods of time. It is well to use a low-freezing grade of the explosive at any time of the year, since this guards against incidental chilling, and since the cap is strong enough to detonate all grades fully.

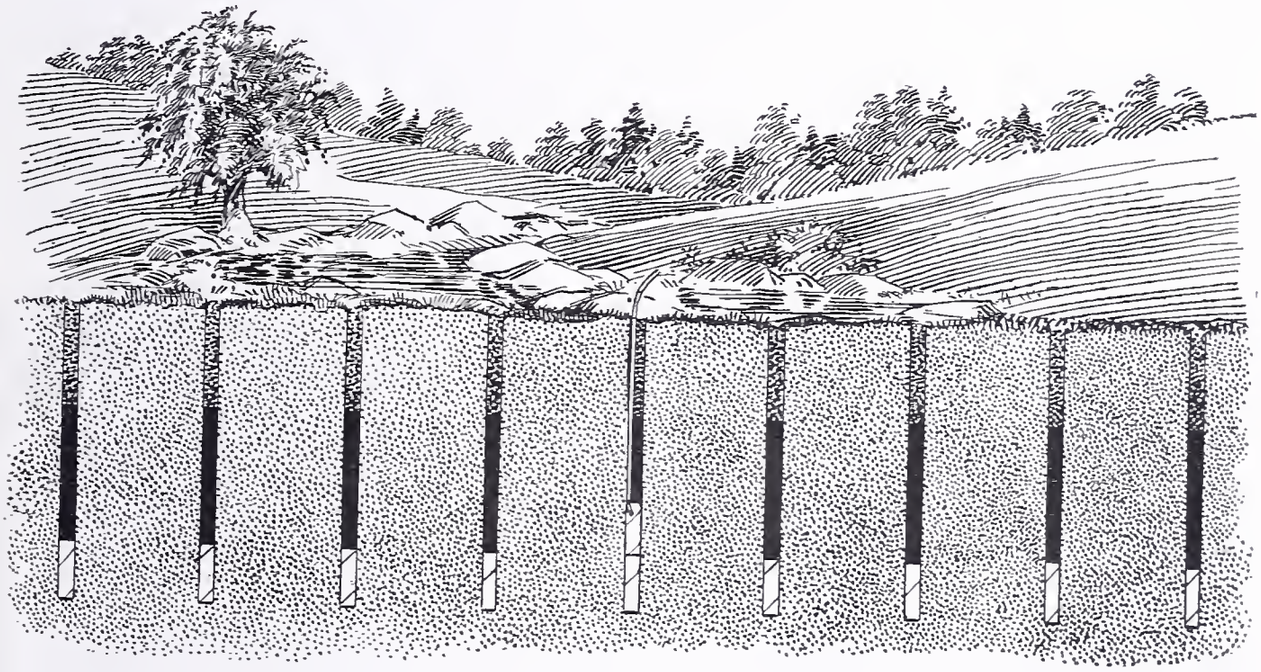
Electric blasting caps, connecting wire, leading wire and blasting machine with the other tools needed for loading, are the supplies demanded for ditch blasting by this method.

Depth for holes, amount of explosive per charge and many other details of the loading are discussed on pages 28 and 30.

Transmitted Firing

When the ditch is to be blasted through ground that is saturated with water, the method of transmitted firing often can be used to advantage. In order to insure its complete and unquestioned success, the water must cover the charges and had better rise in the holes nearly to the surface of the ground.

Under such conditions transmitted detonation can be expected to succeed even in sandy ground and gravel. It is in muck and clay fully saturated with water that the method is most successful.



Showing typical loading of transmitted detonation ditch blast—fuse firing—for 3½′ x 7′ ditch.

Transmitted firing is made possible by the fact that high explosives can be fired by shock (as by that given by a cap, for instance). Under the conditions of soil described above and of proper loading, the shock of the explosion of one charge will travel through the ground and water with enough force to fire the next charge, and so on down the line. So rapidly does this take place that in a line of charges hundreds of feet long you cannot see any difference in time between the middle and end explosions.

If sticks of explosive are laid on a plank a foot apart and one of them is fired with a cap and fuse or otherwise, the others likely will be exploded by the influence projected through the air. In actual ditching work the shock of one

charge cannot be depended on to travel through the ground strongly enough to bring about full and complete detonation more than a couple of feet.

The usual distance apart that is best for charges to be fired by transmitted detonation is 15 to 20 inches. The exact distance in any particular soil at any time must be determined by test shots. Try a shot of 8 or 10 charges (of the amount of powder and at the depth of loading required, as explained on pages 30 and 31), spaced 12, 15, 18, 20, 22, and 26 inches apart.

Careful observation of the blast resulting will show the point beyond which charges fail to explode or explode weakly. The correct spacing of charges, to insure full detonation, will be about two-thirds of this limit.

Spacing of Charges

One charge may fire another at a greater distance than is economical, because it merely may explode it weakly, without developing anything like the full force and speed. And on top of that, each weaker explosion sends a still weaker one on to the next charge, till a point is reached a few charges away where the shock transmitted is not enough to bring about firing at all.

This weakening of the transmitted shock is important, because the strength of an explosion of powder or dynamite depends on the severity of the shock which fires it. For illustration, and not that these figures bear any relation to the true amount of force, if the first charge, the one fired with a cap, gives off 10 pounds of energy in the form of a shock, and this 10 pounds is diminished to 8 pounds by the time it reaches the next charge, this second charge will not detonate with quite 10 pounds of shock energy. It may have only 9 or 8. And in turn, the shock energy from it will be diminished to 6 or 7 on reaching the third charge. If the particular kind of explosive used requires a full 6 pounds of shock to detonate it completely, the transmitted method of firing is going to fail. Even of those charges which do explode, half will give much less than their full force.

Water is not elastic, but air is, and dry soil is and absorbs shock because it contains a good deal of air. The gases of an explosion drive water-soaked

When roots and sod are not cut along the sides of the ditch before the blasting, the edges are never as smooth and as straight as with cutting. An effort was made to trim this ditch up after the blast. It carries water about as well, but it doesn't look to be as good. (In Miller Drainage District, Marion Co., Oregon.)

ground as a steel rod can be driven by a hammer. In it there is but little "give," hence the shock travels with a minimum of loss in force. In dry ground the air cushions the blow of the gases and eases them to a standstill within a short distance. Clay is more solid than sand, which fact explains why transmitted detonation works better in heavy soils than in light ones.

The nature of the ground and the amount of water present therefore largely govern the spacing of charges, though a large charge of course will throw a shock slightly farther than a small one.

As will be seen from foregoing named facts, the effects of lack of water and of light, spongy or sandy ground, can be counteracted somewhat by setting charges closer together. When necessary it is practicable to put them only a foot apart. To put them closer, however, is not practicable, for it costs too much. On the other hand, when the charges are heavier than ordinary—say of two sticks or more—in wet, heavy ground, they may be spaced up to 26 inches apart with satisfaction.

Temperature of Ground

Temperature influences transmitted detonation only by reason of the fact that explosives are less sensitive to shock, and harder to fire when cold than when warm. All grades explode easiest when at a temperature of 70 to 80 degrees. Straight nitroglycerin powder or dynamite must be used at a temperature of higher than 50 degrees. It is not well, for many reasons, to attempt to fire too many charges at once. Several hundred can be fired successfully sometimes, but the usual limit had better be 50 to 100.

When the nature of the ground, amount of water present or temperature are not of the best for securing transmitted detonation, sometimes matters may be helped by taking advantage of the fact that blasting caps are much more sensitive to shock than the explosive itself. Place a common blasting cap, without a fuse, but with the open end filled with tallow, every 25 to 50 feet. These caps may help to restore the diminished force of explosion, making satisfactory detonation extend much farther than it would without them.

A ditch 10 feet wide and 5 feet deep through newly cleared land. The extra width of the excavation helped to tear entirely loose and throw out stumps and roots, leaving the edges comparatively clean of projecting roots. Under such conditions finishing the ditch after blasting is better than to try to cut the edges before. (Paragould, Ark.)

Stones, roots and old logs interfere with transmitted detonation. When these are located in the line of the ditch it is necessary to fire charges on both sides of them as at the beginning. Pay careful attention to changes in soil as you work along the ditch line. It may be necessary to shorten the spacing, or, again, it may be possible to lengthen it and save money.

The firing of the line of charges by the transmitted detonation method is done by loading the required number of charges without priming or with caps and no fuse as described above, all except the center charge of the row. In it place a double charge of explosive, or at least an extra stick of explosive, primed with cap and fuse or with electric blasting cap. Fire this charge in the usual way.

Prime Center Charge

Sometimes an electric blasting cap placed at each end as well as at the middle of the line will fire difficult charges successfully. Once in a while the electric blasting caps may be needed even closer—say every 3 to 5 charges.

The Explosive to Use

The proper explosive for transmitted firing ditch blasting is nitroglycerin dynamite or powder of 50% strength —either regular or low-freezing. The 20% strength dynamites and powders recommended for electrical firing cannot be used at all under this method, because they are not sensitive enough.

Summary of Firing Facts

Transmitted firing requires only the explosive itself, and a cap and some fuse for each couple of hundred feet of ditch, while electrical firing requires wiring, an electric blasting cap for each charge and a blasting machine or other source of current. This advantage of the former method very often is offset, however, by the fact that it requires nearly twice as many holes as electric firing. It is easier to load two sticks in one hole than to make two holes. In addition, electric firing always can be depended on for the desired results, while transmitted firing will succeed only when the ground is full of water. As for quantity of explosive required by each method to excavate any certain ditch where either can be used: In theory the two methods require about the same. In practice, however, more will be used in transmitted firing, unless the work is done very skillfully. The saving in the use of this method comes largely from a saving of electric blasting caps and time, and the need for little equipment.

Preparation of Ground and Loading

During the early days of ditch blasting, before experiments had standardized practices, much objection was taken to the ragged edges of ditches blasted through sod and through brush and woods. The sod would not tear loose and fly away from the ditch. It would either fold back and make a ridge along the ditch, or it would flop back into the ditch after the dirt beneath had blown out. The remedy is to cut the sod and roots along the edges of ditch before blasting.

Cutting Roots and Sod

When there is sod, two furrows should be plowed along the ditch line—one at each edge. Another plan is to cut along the sides of the ditch-to-be with a spade, axe or hay knife. In case the line of the ditch runs past trees, or through brush or forest land, the roots should be cut on both sides the ditch. An axe is needed for the big roots. Where there are many roots the ground should be cut 18 inches deep.

Make the cut at the angle the side of the ditch should have, say about 45 degrees. The blast will clean out the dirt to the cuts and will leave the wall on the outside firm and intact. Cutting the edges of the ditch saves trouble

and work after blasting. It insures that the sides and edges of the ditch will be as straight as though the ditch was shoveled by hand or plowed. But it should not be understood that ditches cannot be blasted without cutting the ground. Except through extremely heavy sod and roots, explosives used alone will clean out good channels when loading and firing are done properly. The cutting of the edges simply makes a smoother, more complete job.

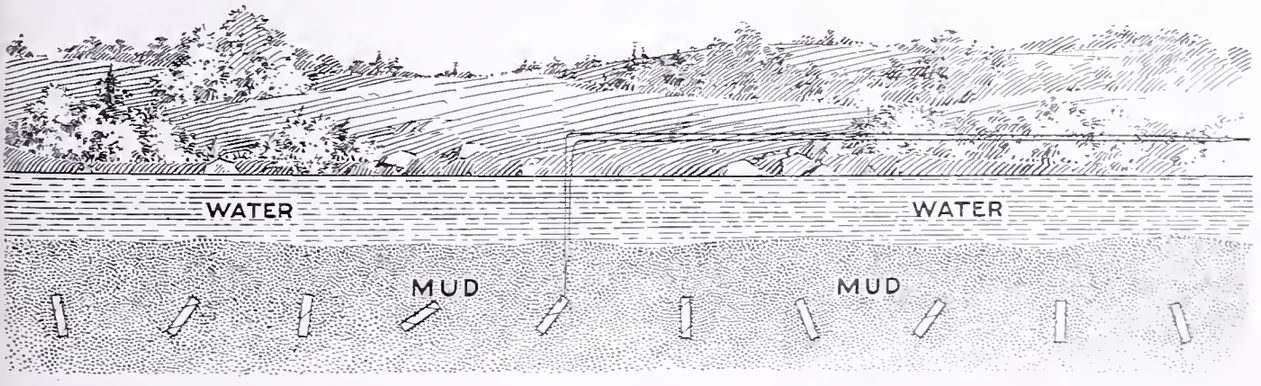
A typical instance of what results from an attempt to blast a ditch through heavy sod without first cutting the sides. The sod breaks loose in the middle of the ditch and either folds back without tearing loose or falls back into the ditch after the dirt beneath it has been swept away. Such ground should be thoroughly watersoaked and the edges of the ditch cut with shovels or hay-knife, or at least by plowing furrows. (Virginia.)

Locating Line For Holes

The charges should be placed along the center line of the proposed ditch, except where the ground is harder, or higher at one side than at the other, when they should be placed 6 to 12 inches from the center toward that side. The eye is not capable of keeping the line of charges true. Stretch a string where they should go. In making the holes the man should have a measuring stick to space them accurately. Guesswork on this point is likely to be expensive.

Make the holes straight down into the ground. The practice used to be to make them at a 45 degrees slant, but this offers no advantage in any way.

It is much easier to make holes in soggy ground than in dry ground. In fact, it is almost impossible to sledge down a bar in some dry ground. When there are no stones, a soil auger often is of advantage, though the bar and sledge are hard to beat for speed and results. The only modification of the up-and-down position of the sticks or charges that is desirable is when you are deepen-



Typical loading for deepening ditch with bottom of mud—electrical firing of center charge for transmitted detonation.

ing ditches already made, with bottoms of thin mud or thick muck. In such material you need punch no holes. Just push the sticks into place down in the mud with your hand and place them in a horizontal position lengthways of the ditch.

If you have a windy day for the blasting, with the air drawing strongly across the line of the ditch, you will be surprised to see how far the falling dirt will be carried away from the ditch during the few seconds it is in the air. On a quiet day, 6 to 12 inches of dirt will fall back into the ditch. On a windy day your finished ditch will be several inches deeper and wider than on a calm day. Do not take from this that a windy day is demanded for satisfactory results. The force of the blast spreads and scatters all but a little of the dirt. The wind merely helps.

Preventing Dirt Falling into Ditch

An explosion throws the earth so high that the slight additional depth or height of sides met with in deepening a ditch does not interfere materially with the excavating action of the blast. Probably a little dirt is caught and rolled back by the side walls, but the percentage of the total lifted is small.

When water covers the charges, be sure to make the primed sticks, and the cap and fuse, waterproof with tallow or paraffine at points where they join. Shoemaker's wax is another good thing, but is expensive. Tar and thin lubricating grease are very poor materials for waterproofing.

Waterproofing Charges

When water covers the charges you should arrange to load them and to fire them quickly. A good plan is to make all the holes for one section, then prepare the charges, as to priming and waterproofing and distributing them along the line. Quickly test each hole for fallen stones, caved-in dirt, and push the charges to the bottoms of the holes. It is best to limit their soaking to a half hour. The explosive is likely to weaken if left too long.

If the holes cave in soon after the bar is withdrawn, do not attempt to load and blast long sections at a time. In loose gravel and sand, especially where water cover the surface or nearly so, you will have trouble getting the charges down to the bottoms of holes. The best plan is to get a tin tube about 1½ inches in diameter and sink it in the hole over the bar. The explosive then can be loaded without trouble when the bar is withdrawn.

Tamping Ditch Charges

Generally speaking, a ditch charge should be tamped slightly. The more tamping you use the broader your ditch will be in proportion to its depth. If you want a narrow ditch you must let the gases rip their way upward easily. In dry or damp ground, fill the hole about half full and tamp well. When water rises high in the hole, use no tamping at all, except to tramp shut the upper 6 inches.

The ground had better be warm for ditch blasting. If it is cold you must load and fire the charges quickly, to prevent chilling of the explosive. A light

crust of frozen ground makes little difference when charges are handled properly; more than ¼ to ½ inch will interfere seriously.

Regulating Depth and Width

The dirt will clean out 6 to 8 inches deeper than the bottom end of the charges when conditions are normal. Explosives work more efficiently in ditch blasting when they are placed as shallow as possible. When the holes are too deep an excessive amount of explosive is required. A layer of hardpan or cemented gravel in the ground to be removed requires slightly deeper placing than soft ground. The rule for the usual job is to place the charges within 6 inches of the bottom depth desired, and for large ditches and heavy charges within 10 or 12 inches of the desired depth. The exact depth may be ascertained by trial shots.

Depth for Charges

The greatest depth it is practicable to blast at one shot is about 6 feet. If a deeper ditch is wanted, blast a second time in the bottom of the first excavation. (See table on page 31 for depths for charges.) The blasting out of very large canals should proceed along these lines. They involve no principles not explained for the making of small ditches.

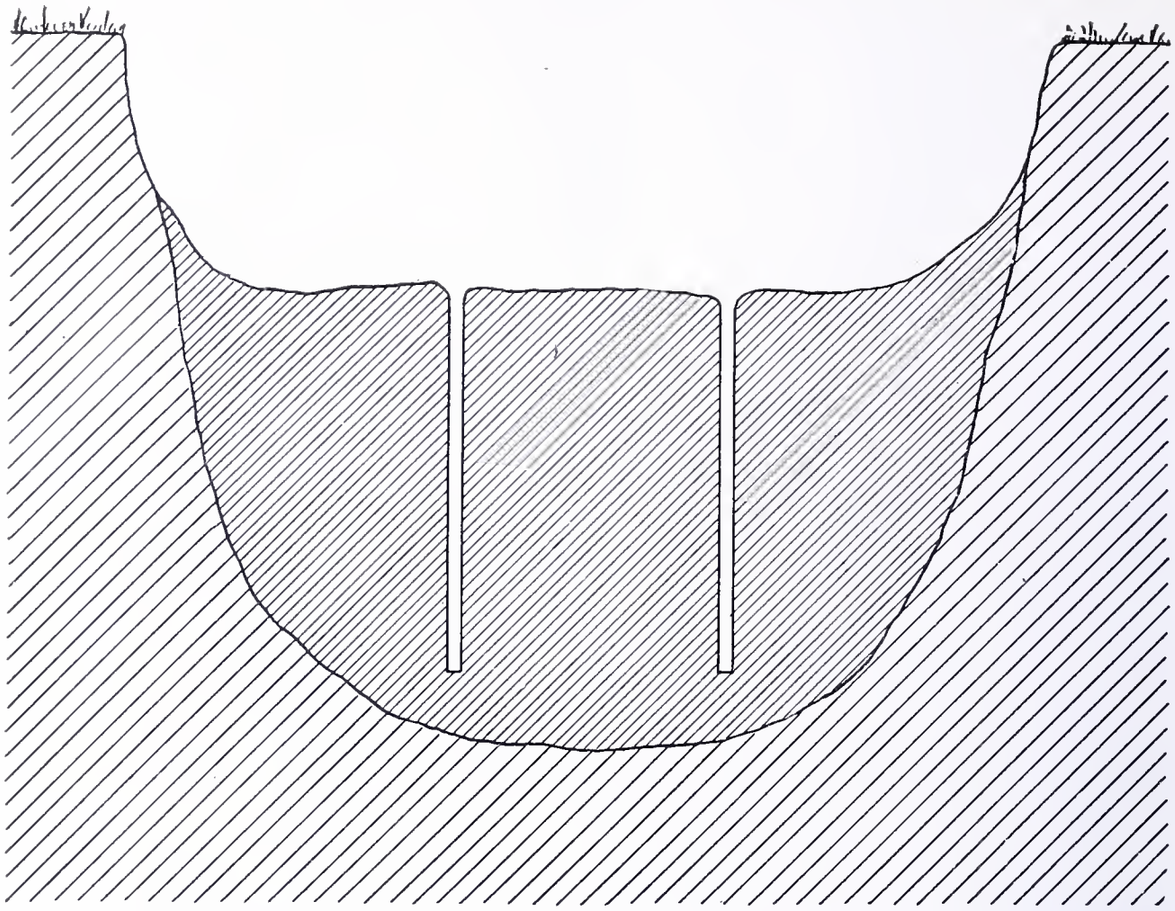
A channel 35 feet wide and 6 feet deep that was excavated by blasting. The water has smoothed the sides a little, but in the main the big ditch looks in the picture as it looked after the blast which opened it. The cost of such ditching can be figured accurately in advance when dimensions are known, the kind of soil and its condition considered, and the cost of explosions at hand. (Athens, Ga.)

One line or row of charges frequently will make a ditch up to 12 feet wide and 6 feet deep. To make wider ditches use 2 or more rows.

Wide Ditches

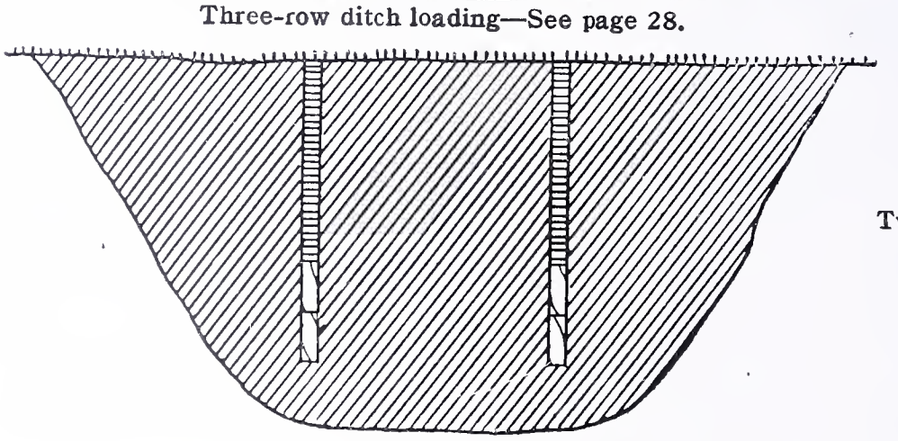
Usually 2 rows of charges will be needed for ditches between 8 and 12 feet wide if less than 4 to 6 feet deep, and 3 rows for ditches 12 to 18 feet wide.

The lines or rows of charges should be placed about 4 feet apart, except where the charges consist of more than 4 sticks and are close together in the rows on account of transmitted detonation, when the rows may be as much as 6 feet apart. In blasting out very wide and shallow ditches or canals, it sometimes is of advantage to load 2 rows with light charges rather than to attempt to blast out

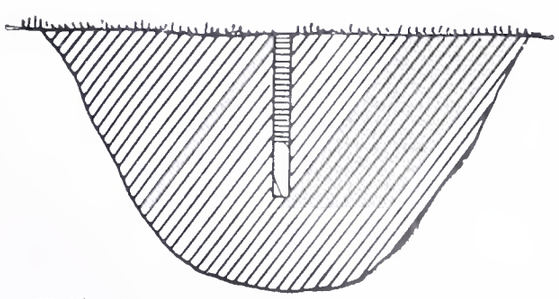


How to deepen ditch by a second blast in the bottom of a first excavation.

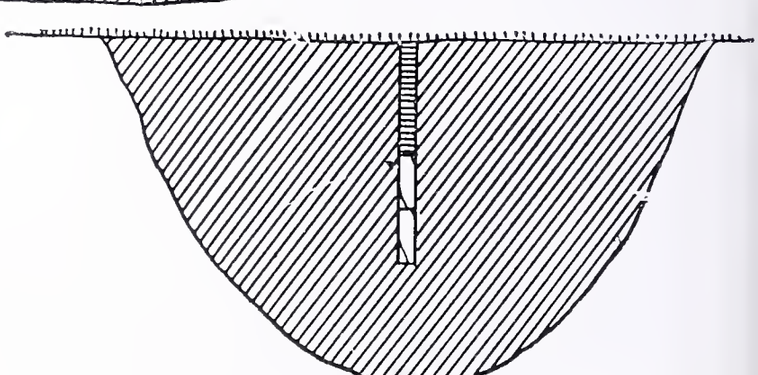
Three-row ditch loading—See page 28.



Two-row ditch blast loading.



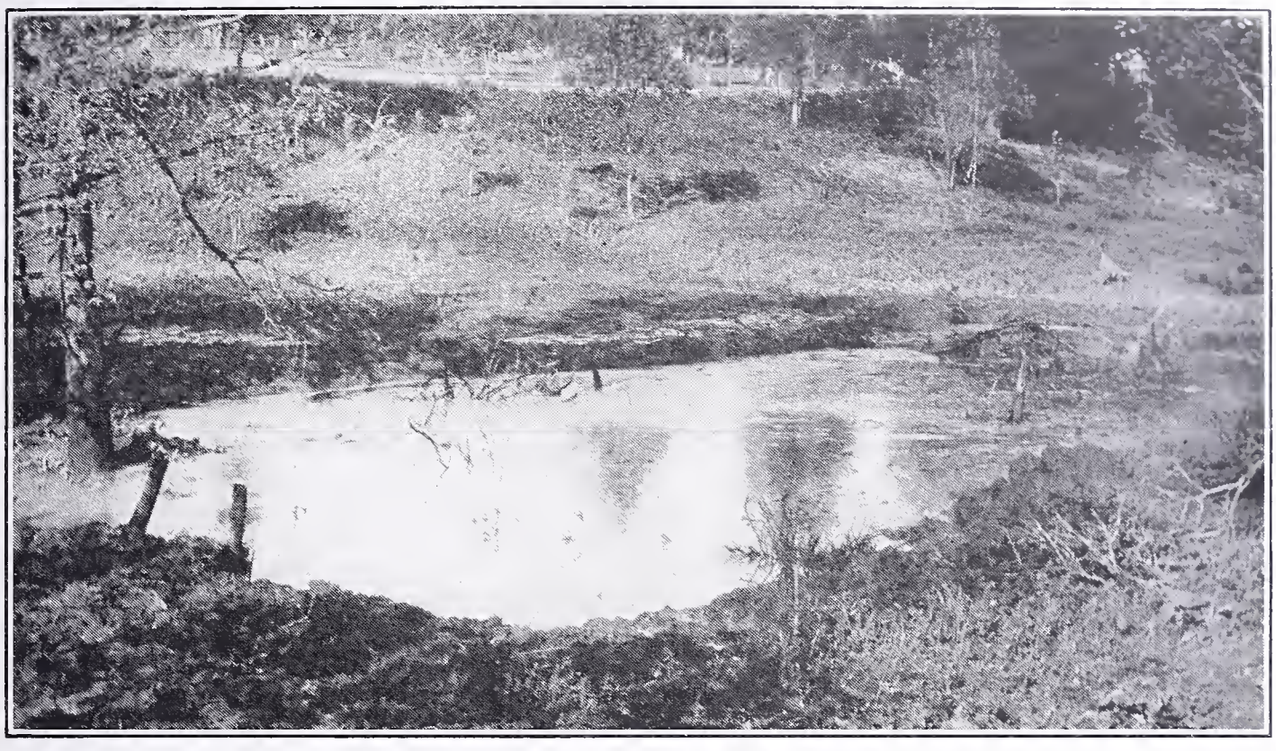
Half stick loading for very small ditch.



Single-row loading for large ditch—if larger ones are needed, more rows of charges.

the ditch to the required width with one row heavily loaded. The heavy charges might dig deeper than required. (See table on page 31).

Invariably all the rows should be fired together. This, of course, is accomplished when the electric method of firing is used. When using the transmitted detonation method, put in extra charges between the rows at the center charges, and then fire one—usually the center charge of the middle row—with a cap and fuse. All these center charges and extra charges should be *heavier than usual.* Put in an extra stick, at least. A still better way with transmitted detonation is to fire the center charges of all the rows together electrically.



A pond excavated entirely by blasting. Several rows of charges were loaded and fired simultaneously. The wind carried the earth to one side, forcing it to fall on adjoining ground instead of back into the hole blown out. (H. E. Ellis, Ashland, N. J.)

Amount of Explosive Required

Before giving tables of the average amount of explosive required for various sized ditches, it is well to describe a few typical examples of ditches that have been blasted, of which records were kept.

Examples

In a clay soil, with water rising almost to the surface of the ground in the holes punched for charges, charges of one stick of straight nitroglycerin explosive placed 18 inches apart and 30 inches deep blew out a ditch 4 feet deep, 3 feet wide at the bottom and 7 feet wide at the top.

In a similar soil, with less gravel, charges of one-half stick of straight nitroglycerin explosive placed 15 inches apart and 18 inches deep made a ditch 2½ feet deep and 5 feet wide. At another point in the same field, on the same day, charges of 2 sticks (one pound of same explosive), placed 30 inches deep and 24 inches apart, made a ditch 9 feet wide and 4 feet deep.

In loam ground, too dry for successful transmitted detonation but still somewhat damp, charges of 2½ sticks placed 2½ feet deep and 3 feet apart, and fired electrically, cut a ditch 4 feet deep, 8 feet wide at the top and 2 feet wide at the bottom.

Through a thicket with brush and small trees measuring 1 to 3 inches in diameter, in heavy pure loam well soaked with water, charges of 2 sticks of

straight nitroglycerin dynamite placed 22 inches apart and 3 to 3½ feet deep made a ditch 4 feet wide at the bottom. The ditch was loaded too heavy. Charges of 1½ sticks would have been better.

In very wet and miry clay, a ditch 20 feet wide at the top, 12 feet wide at the bottom and 6 feet deep was blasted with 3 rows of charges of straight nitroglycerin explosive. All the charges were spaced 20 inches apart in the rows. The charges in the middle row were 1½ to 1¼ sticks, varying a little on account of variations in the soil along the ditch. In the two outside rows the charges were one stick each. The rows were placed 4 feet apart. One section of the same ditch was cut out to a depth of nearly 8 feet by using 1½ sticks to the charge in the 2 outside rows, and 3 sticks to the charge in the middle row.

When the ground is fairly heavy and is full of water you can count on each pound of explosive properly placed to clean out 1½ to 2 cubic yards of earth.

Amount Excavated By One Pound of Explosives

The variations from this rule, both ways, will be on account of the presence or absence of water, the nature of the soil and the size of the ditch. A ditch made with a single line of charges (measuring, usually, 3 to 4 feet deep by 3 feet wide at bottom and 6 to 7 feet wide at top), will give the highest efficiency, and when the conditions are very favorable will show even a little more than 2 cubic yards per pound of explosive used.

As the amount of excavation in one body increases, the efficiency of each pound of explosive will fall off somewhat. In very large ditches that are wet you will get out only 1½ cubic yards per pound of powder. In dry ground blasting, particularly if the ground is light, 1¼ or even one cubic yard per pound will be the average.

Number of Half-Pound Sticks of Explosive Required per Charge for Blasting Ditches

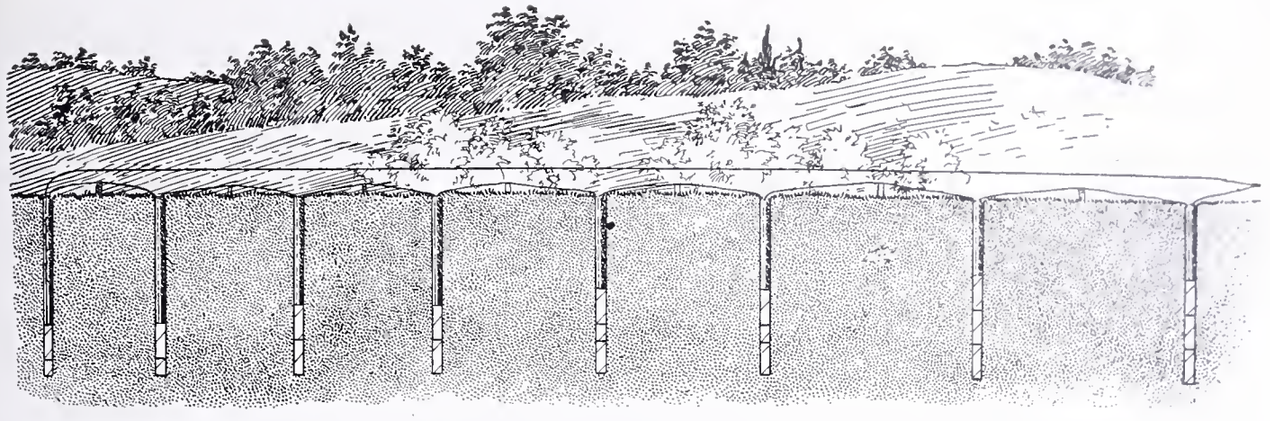
Depth Ditch	Depth Hole	Amount Charge Transmitted Detonation	Amount Charge Electric Firing
2 ft.	1½ ft.	½ stick	½ stick
2½ ft.	2 ft.	¾ stick	1 stick
3 ft.	2½ ft.	1 stick	1¼ sticks
4 ft.	3¼ ft.	1½ sticks	2½ sticks
5 ft.	4¼ ft.	2 sticks	3½ sticks
6 ft.	5 ft.	2½ sticks	5 sticks

The width of the ditch can be calculated by doubling the figure for the depth in case of a single row of charges, or in the case of more than one row, by adding to the figure for double the depth the distance between the rows of charges.

The table given above is correct for average conditions. Since variations in soils, temperature and other factors make necessary varying loading, the figures here should be used as a guide for starting test shots.

No ditches should be blasted without testing the loading thoroughly before proceeding with much work. Blast small sections at a time, and vary the loading to suit the changes in the nature and condition of the ground you encounter along the ditch line. Clay, sand, muck, loam and gravel all require variations in depth of charge, amount of explosive and sometimes in spacing of charges. Proper tests will enable you to decrease the cost and to make a better ditch than otherwise would be possible.

Making Test Loadings



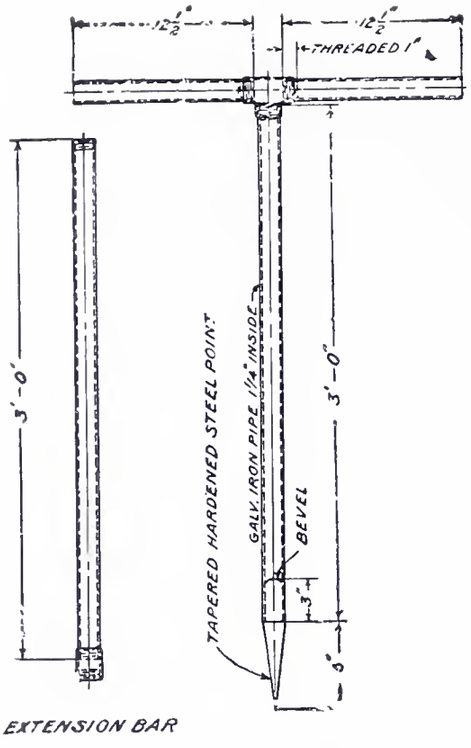
Typical test loading to determine proper charges and placing of explosives for electrical firing. Note the variations in spacing between holes as well as in amount of explosives used. (See page 23.)

Five to ten holes make a good test. This should be repeated several times. Vary the depth and spacing and the amount of charges. *Remember that proper blasting will make perfect ditches at low cost, and that the only final way of determining proper loading is to try it.* Well-balanced charges will be so loaded and spaced that the gases will lift the full load of dirt without overlapping much and without skipping any ground between. Load just heavy enough to insure clean excavation without excessively high throwing of dirt.

Time Required

Making 3-foot holes in clay and gravel, preparing charges, loading and firing can be done by one man at the rate of 20 to 50 charges per hour. If there are many stones in the ground, or if the ground is hard, the work will go slower. Wet gravel makes slow work. Two or more men will get more done in proportion than one man. Under favorable conditions one man has blasted out 1,000 feet of ditch 3 feet deep in 12 hours. One man should be able to blast 350 to 450 feet of ditch per day through brushy ground; if the land is clean he can do more, though where ground is so dry as to cause trouble in making holes, the work will go slowly.

A crew of ten men—eight laborers, one blaster and a boss—working at a big ditch. The employment of so many men is not justified except for very long ditches, for the job lasts only a day or two. A good sized crew enables the blaster to place and to fire the charges quickly, which is an advantage when the holes fill with water and when the temperature is low. (Max Ostner, Diehlstadt, Mo.)



How to use pipe to make a punch bar or to extend an auger.

Ditch blasters should have a soil auger, two crowbars, a sledge, a couple of long-handled shovels and a cutting spade. One of the bars should be 4 or 5 feet long and should be constructed for driving. The other should be 6 or 7 feet long, and may be made of piping, with a solid sharp steel point welded in. It is for use as a churn drill, without sledging. A broomstick or a wooden rod about 1½ inches in diameter, for pushing the charges down and tamping, and an axe to help cut roots, also are handy. Of course, boxes or baskets for carrying explosives, cap crimpers and the usual outfit for handling and loading explosives as described on pages 36 and 37, will be required.

Tools Required

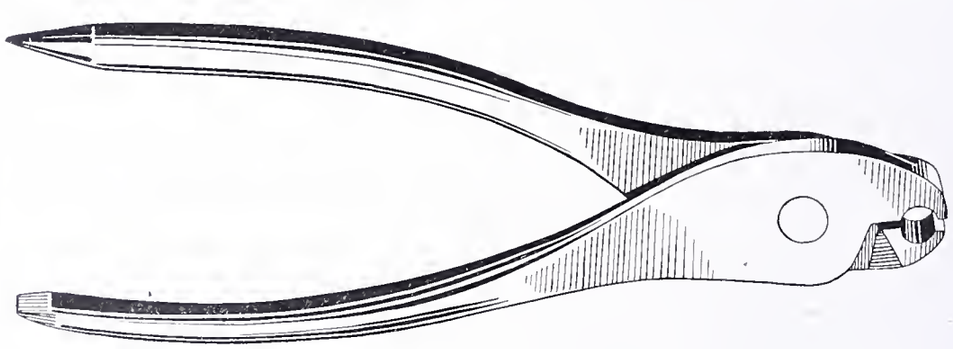
Incidentals

Large stumps, stones or other obstructions along in the line of the ditch require a little extra explosive. Stumps up to 6 inches through and boulders up to 18 inches in diameter will be thrown out by the regular ditch charges

Steel bar for making holes.

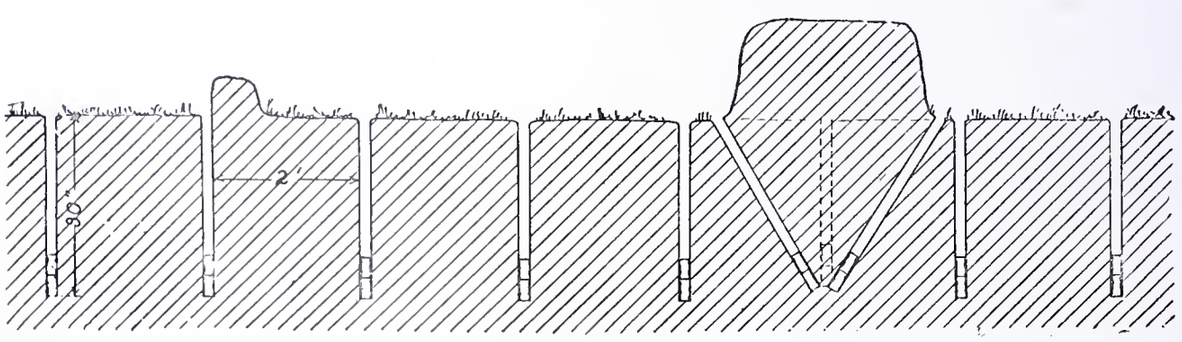
Soil auger—note long point.

Above these sizes use extra loading, as follows: For each 6 inches of the diameter, use one stick of explosive. For stumps larger than 30 inches, use 3 to 4



A good kind of crimper.

sticks for each foot of diameter. Put the extra explosive directly under the stump or stone.



How to place charges under obstructions in the ditch line.

Through heavy sod, as shown here, blasting cuts the sides somewhat irregularly unless the grass roots are first sliced with a shovel blade or hay-knife. This ditch is well opened and entirely successful, but a good many projecting chunks of sod are left sticking from the sides.

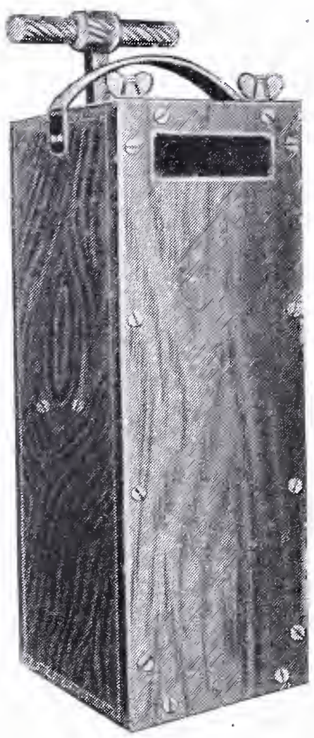
Finishing Ditch

Ditches blasted through ground that has a raw surface and no roots will require no finishing afterwards. The edges and sides should be fairly true and even and the dirt should be well scattered. There will be few or no ridges along the ditch. Even through sodded ground and through woods and brush, when the sides of the ditch have been cut before blasting, there will be little hand work needed. If no preparatory cutting is done, however, some shoveling to smooth the sides and some cutting to take out projecting roots and sod may be advisable.

This ditch was blasted out on a still day, and most of the dirt fell straight back to the ground. But it was spread out so that only a little of it fell in the ditch. The few roots projecting into the excavation can be cut off with little trouble. It is the roots of sod and matted roots of smaller brush and trees which give the trouble in blasting and require cutting beforehand. (Robert Jemison, Birmingham, Ala.)

This work should be done right after the blast, before the water has a chance to compact the sides. If necessary, leave dams of unblasted sections 3 or 4 feet long every few hundred feet in the ditch, to hold back the water long enough for finishing. They can be blasted out afterwards. An old axe or a sharp grubbing hoe or adz will cut the ends of roots easily. But all this work can be avoided and a better ditch result if you will do the cutting before the blasting. Large clods, pieces of stumps or roots and stones in the ditch channel after blasting should be thrown out without delay.

It has been stated (page 12) that ditches for tile or pipe cannot be blasted out satisfactorily. The dirt can be loosened with light charges, however, and the shoveling or excavating by other means thereby made much easier. If the pipe is to be placed deeper than 4 feet, it even is practicable to blast a 3-foot or deeper ditch on top, leaving only a little more excavating to do in the bottom. One must bear in mind, however, that the blasting throws dirt too far away to be shoveled in to cover piping. Loosening as explained above, however, to make digging easier, does not throw the dirt away.



Two post electric blasting machine—
push down type.

Preparing Charges of Explosives for Firing

What a Charge is

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the stick of dynamite or powder (see pages 37 to 39) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

All who use and buy explosives should read the next chapter, beginning on page 51, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at a slight slant of, say, 30 to 45 degrees from right angle.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the stick to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the stick. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the sticks to the bottom of the hole (see page 43) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

Protection of Explosives

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep

out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

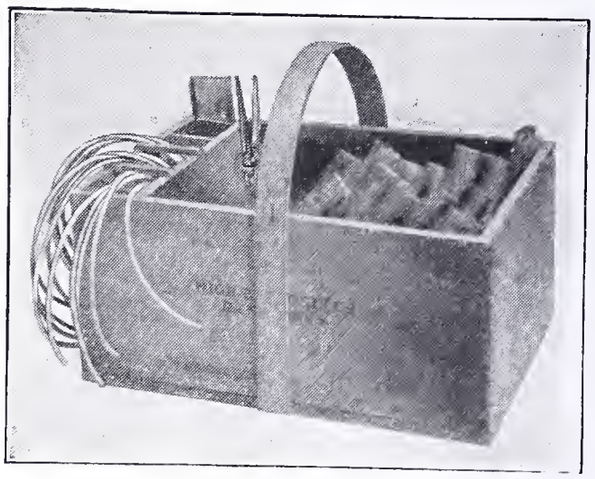
Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 60 to 61 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many sticks of explosive (or parts of stick, if charges are to be less than full sticks) as there are holes to be primed; an equal number of caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocket knife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material. In certain cases a sharp hatchet or axe and a block of wood will be worth having. The purpose and use of these items will be made clear later.



A handy box for carrying supplies to field.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 60 and caps on pages 58 to 60. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 61).

The Fuse

Three feet will give you 1½ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.

Cut the fuse off at a very slight angle or bevel—say 30 to 45 degrees, as shown in the diagram. This slant is for the purpose of giving a little space between the actual end of the powder and the explosive material in the bottom of the cap, to enable the spark to spit into material.

Cutting the Fuse

The only way to regulate the space is to cut the fuse as directed and let the long tip rest gently against the bottom of the cap. The spark has a better chance to ignite the explosive material in the cap when it spits from the end of the fuse than when it merely burns up to the end without any space to spit into.

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimpers or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Another good tool is a sharp axe, to be used on a block of wood. The method of cutting is of small importance, just so the actual cut is made smooth and even enough. If you do use other tools, have a knife with you to trim up ends that are not true. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

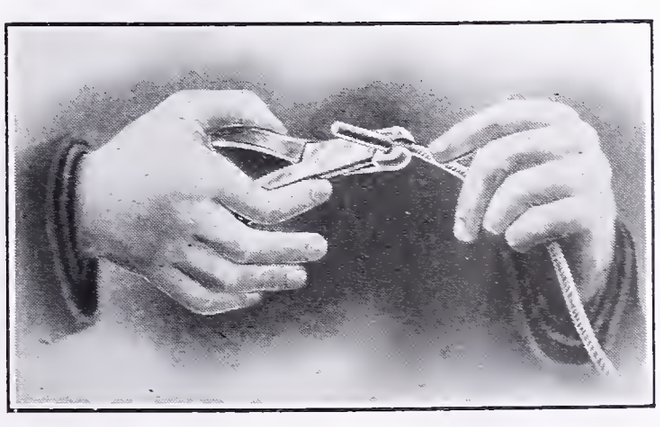
To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

The Cap

Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier-like tool called a cap crimper. The "crimp" is made by pinching the open end of the cap tight to the fuse. It should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

Crimping

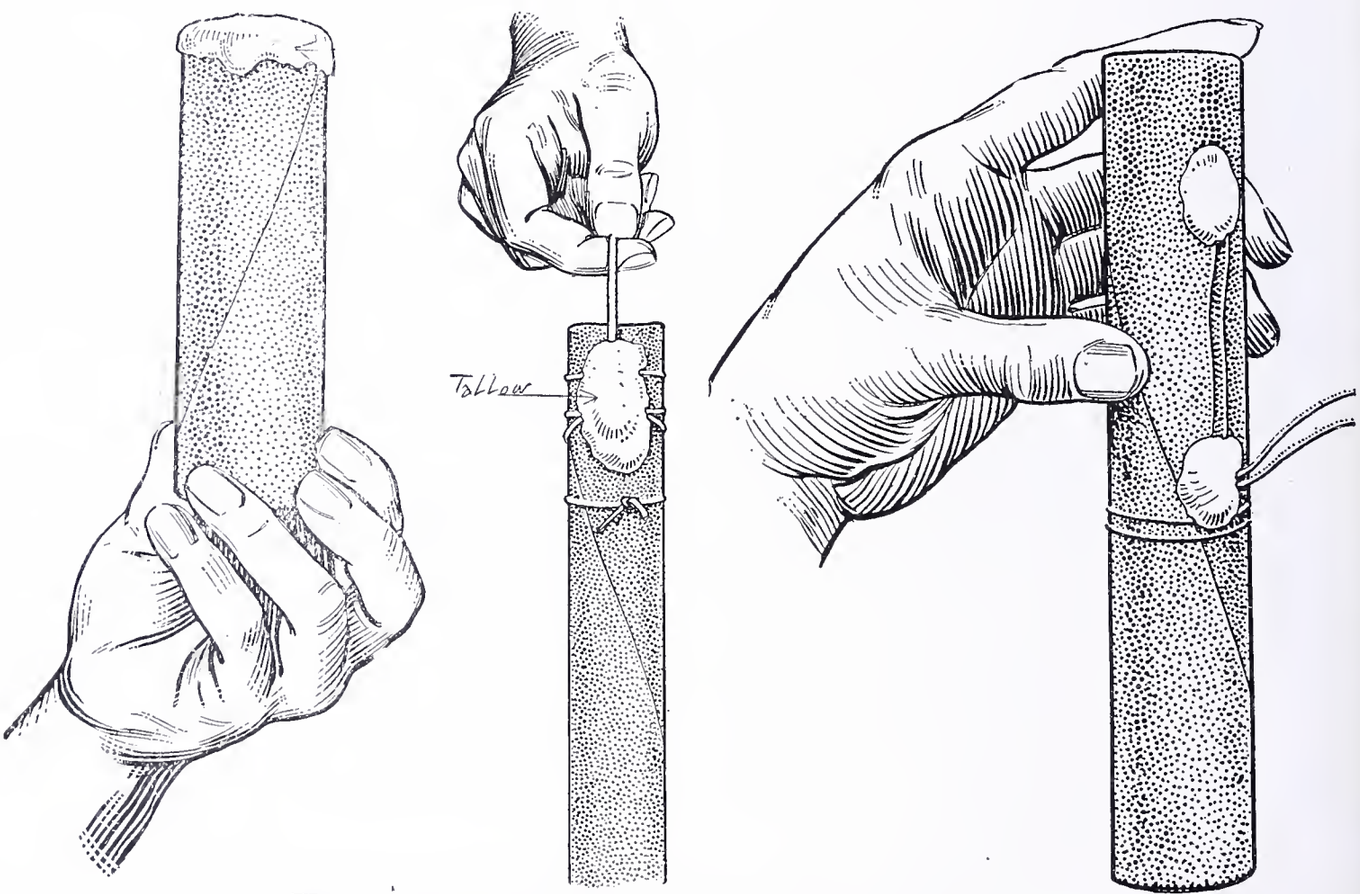


"Crimp" or fasten caps to fuse with a regular crimping tool. This tool does the job far better than it can be done in any other way.

Cap crimpers are supplied by

all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty —which is to secure a makeshift crimp with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.



Waterproofed (tallowed) sticks ready for loading in wet holes.

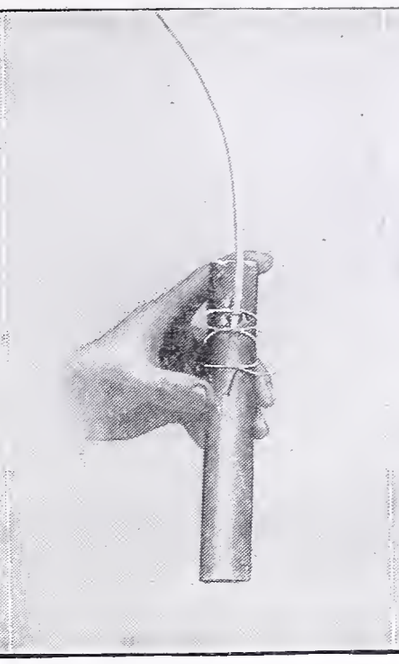
Waterproofing

When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

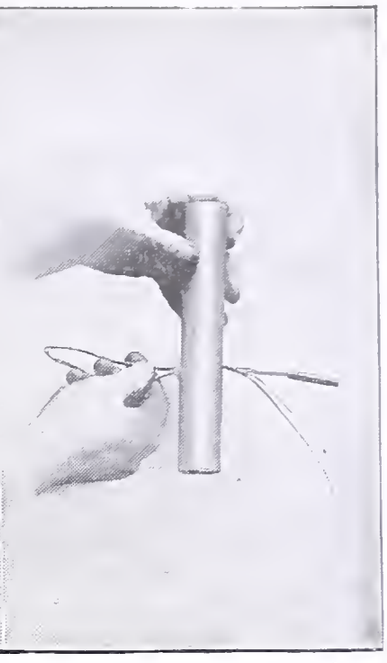
Inserting Caps in Explosive

The best location for a cap in a stick of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the stick, as possible.

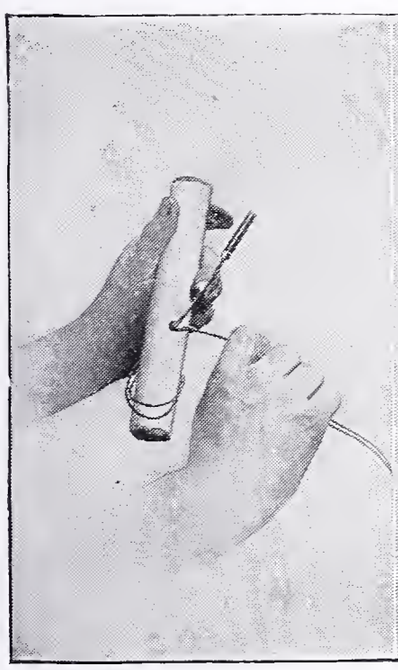
Crimping cap with the cap crimper.



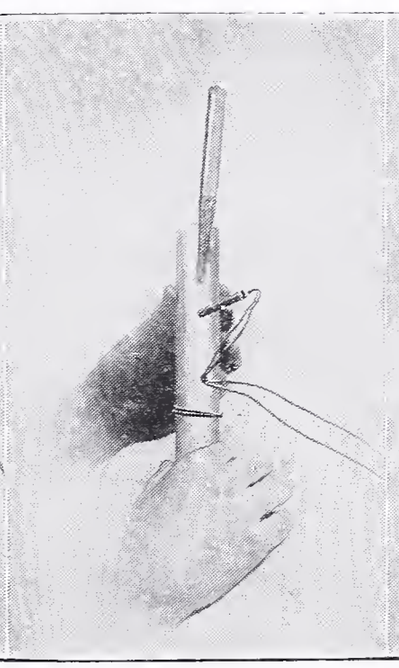
Fuse tied firmly to stick with string.



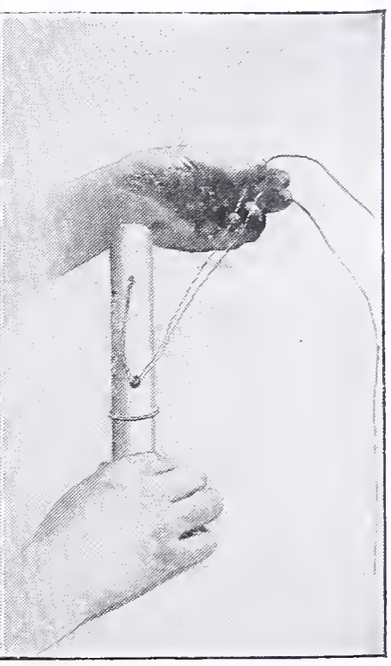
Electric Blasting—Pass the doubled fuze wires through a hole in stick of powder.



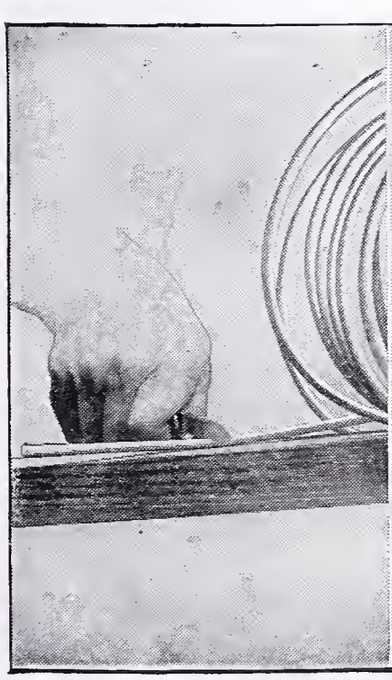
Loop the doubled end of fuze wires over end of stick.



Pull loop tight, bend wires at cap, punch slanting hole in stick high up and round to side a little.



Insert cap in slanting hole to bend of wires, take up slack in wires. (Waterproof holes if ground is wet.)



In cutting fuse from roll use sharp knife.

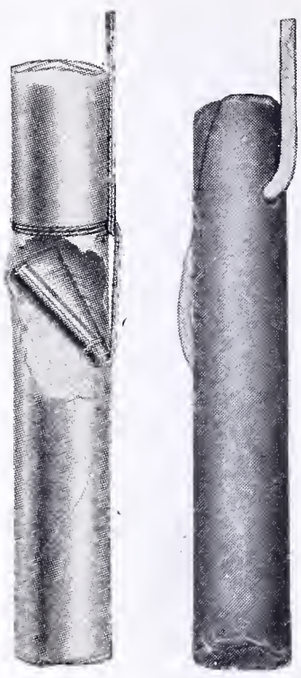
Taking one cap carefully from box.

Inserting fresh end of fuse in cap.

Position of Cap in Stick

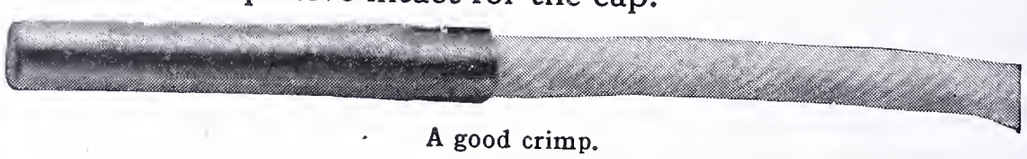
In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the stick as possible. There are reasons for this connected with superior or inferior detonation.

Another style of priming much used is to set the cap in a hole made in the end of the stick of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but experience shows that the tamping stick often bends the fuse over sharply when the primed stick is pressed into the hole and sometimes even interferes with the cap itself. With side priming there is a cushion of the soft explosive between the end of the stick and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.



Bad priming.

When all the explosive is removed from its stick wrappings, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a stick. But it seldom pays to take all the explosive out of stick wrappings. Nearly always you can leave a half stick of explosive intact for the cap.



A good crimp.

Making Hole in Explosive

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced on down to the bottom, which will leave some of the fuse in contact with the explosive (may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

Fastening Fuse to Explosive

When the cap is seated in its hole in the side of the stick, the fuse will extend up along the stick past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the stick is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the stick.

Cutting stick in two—roll it under knife blade.

When the foregoing directions have been complied with you have a stick of explosive primed with a cap and fuse. It is ready to put in the hole in the rock or ground.

Loading Charges in Holes

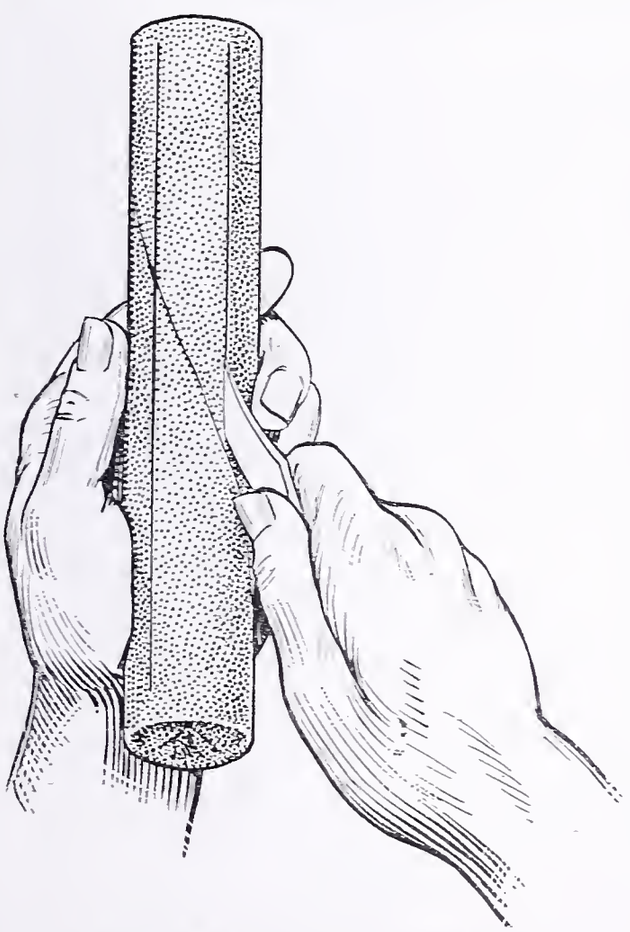
You will need a tamping stick. This must be of wood, and had better be about the size of a stick of explosive, which usually will be 1¼ inches in diameter, except in case of blockhole blasting of boulders, when a smaller stick sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow sticks of explosive to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the stick wrappings and crumbled and pressed into the hole). Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don't try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

Tamping rod

Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives

The tamping rod should be of wood.

should be as much on a pile as possible. If one or 2 sticks are all the explosive required, it usually will not hurt to put them end to end. But if 3 or more sticks are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.



Slitting the paper wrapping of stick to let it swell to fill dry hole.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a stick as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 51 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the

sticks to enlarge and fill the hole solidly. To accomplish this enlargement of sticks, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to 6 sticks in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the stick wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed in, funnel it down to the bottom of the hole. But neither this method nor slitting the sticks is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the sticks intact. Ammonia powders or dynamites will not stand wetting inside the paper of the sticks without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do).

When there is more than one stick in the charge, place the primed stick on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the sticks. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The sticks of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

Tamping

Tamping

Tamping is a necessity. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives. The rule for the least contents of tamping that will do good work is that it should be 6 or 7 times as deep as the hole measures in diameter.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made *wet* enough to ball. In fact, there isn't much better tamping than water itself in the hole, when it can be made to cover the charges deeply enough. Use the heaviest earth within reach, and if it is dry, better carry some water for wetting it.

Firing

Stick the burning head of a match against the powder to light fuse surely.

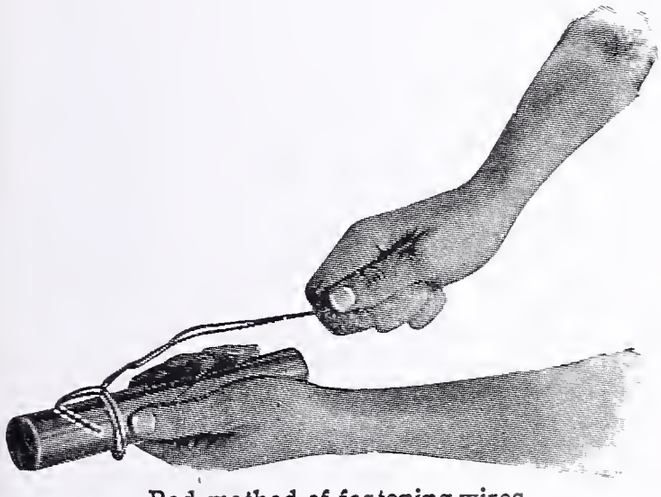
The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut.

Preparing Charges for Electric Firing (Making Primers)

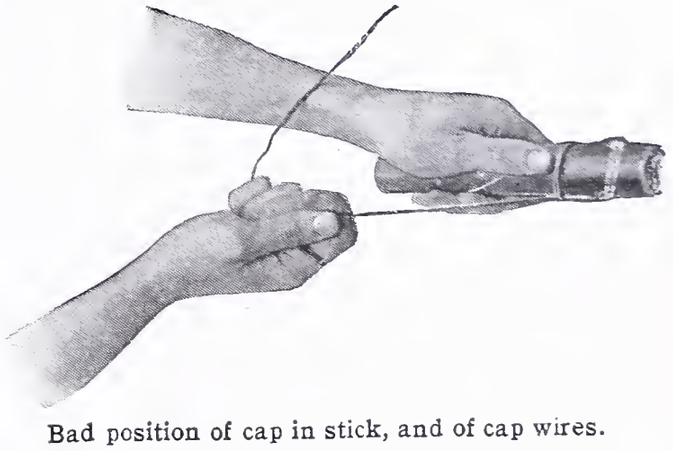
Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 59 and 60.) They are ready to be inserted in the stick of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the stick of explosive just as is described on page 41. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the stick with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.



Bad method of fastening wires. It is better to tie them.



Bad position of cap in stick, and of cap wires.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to pass the wires through the stick. To do it punch a hole straight through the stick of explosive about the middle. Double the wires about 6 inches back of the cap and pass the doubled end through this hole. Then loop the doubled ends from the other side back round the lower end of the stick. Take up the slack in the wires and you will have a sure fastening. The cap can be inserted in the stick at another point, in a slanting hole, just as described previously.

In fixing wires of electric blasting caps to sticks, avoid crossing them and avoid bending them sharply or in any manner that will break their insulating. If the insulating is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the stick with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed sticks the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulating on the wires with small stones in the hole or with the tamping rod.

The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 55 to 57. Further discussion is not needed at this point.

Some General Suggestions

In priming sticks of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the stick of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the stick of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed stick of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another stick, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed stick of explosive by the fuse or wires when it can be helped. When a practice of carrying primed sticks by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the sticks waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the sticks, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the sticks. Pay particular attention to waxing or tallowing the place where the cap and wires go into the stick.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain of course, will damage it.

Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamental facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of sticks and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Another familiar term is powder. Other names are farm powder, quarry powder, contractor's powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P., giant powder, blasting powder and dozens of others.

Names

Nearly every one of the explosives designated by these names are made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Differences

Nor is the difference one of size of stick or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other properties.

Explosive Ingredients

The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of

which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as sticks of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so dangerous and unstable that it must be mixed and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the powders and dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as "straight dynamites" and "straight powders" are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers "extra" dynamites and powders. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosive powders on the market are not so named that their ingredients can be determined without a statement from their makers.

Strength and Quickness

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.

For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia powders and dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin powder is more violent than a 50% ammonia powder, and a 20% ammonia powder is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 50, also detailed recommendations on pages 22 and 25.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They *must* be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a stick, or to handle the frozen explosive in the ordinary way. (See pages 51 and 52 for directions for thawing.)

Regular nitroglycerin explosives are quickest to freeze. Others, known as "Low Freezing," will stand much lower temperatures without showing trouble in this respect.

Freezing

Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down to at least 25 degrees, and in practice many of them can be used right out in the open without any trouble when the temperature is down to zero and below. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When high explosive

powder or dynamite is frozen, the sticks will be hard, and when it is partly frozen they usually will have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the sticks should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 50) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and powders and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Other Properties

Dynamites and most high explosive powders are light-colored materials that look like fine, sticky sawdust, and they always are packed in "sticks" made with cylinders of tough paper. These sticks vary in diameter and length. The standard is 1¼ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. You can get special sizes of sticks if you need a considerable quantity, varying from ⅞ of an inch in diameter to 4 inches. Sizes other than the standard 1 ¼ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Appearance of Explosives

Dynamites and high explosive powders are packed in wooden boxes containing 25 pounds or 50 pounds, as you prefer. A 50-pound box of 20% ammonia powder or dynamite will contain about 105, 1¼ by 8 inch sticks. If of 20% nitroglycerin, it will contain about 98 sticks. If of gelatin dynamite, or blasting gelatin, it will contain about 88 sticks.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There

would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosive cost much more than the latter.

To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 21 and 25.)

Explosives Recommended for Different Work

Stone blasting—mudcap	Straight nitroglycerin or ammonia dynamite, 50% or 60%.
Stone blasting—undermine	To break, same as for mudcapping; to throw out, use any dynamite or powder of 20% strength.
Stone blasting—blockhole	To shatter well, any high percentage dynamite or powder; to break into large pieces, 20% ammonia dynamite or powder.
Soil blasting—for subsoiling and for tree planting	20% ammonia dynamite or powder.
Ditching—electric firing	20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.
Ditching—transmitted detonation	Straight nitroglycerin dynamite or powder, 50% strength.
Stump blasting—in medium and heavy soils, wet or dry	20% nitroglycerin or ammonia dynamite or powder.
Stump blasting—in dry sand and other light soil	50% nitroglycerin or ammonia dynamite or powder.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of their grades and brands would be most suitable.

Detonation

Firing, Exploding or Detonating

It is well known that black powder is fired by a spark, and that dynamites and high explosive powders cannot be fired by a spark but require a shock and heat. It is not so well known that there are great differences in the nature and effect of the explosion of any powder or dynamite, due to variations in the way it is fired.

An explosion of powder or dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of powder. The kind and amount of gases produced by any

high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.

The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the stick of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up *complete* detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Cap Means Detonator

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite or powder, although in the field and among manufacturers the same articles are called by the terms "detonators," or "electric exploders."

Thawing Explosives

It has been pointed out (on page 49) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

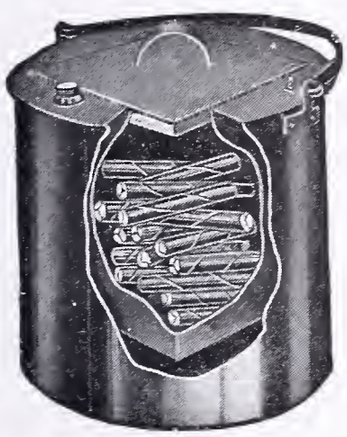
Frozen dynamites and powders are dangerous materials, and whenever the temperature is near the freezing point for them, the sticks should be

inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites and high explosive powders will be a little soft to the pressure of your thumb when they are not frozen.

Frozen Explosive

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The sticks may explode when dropped to the ground or floor, when sticks are broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen sticks of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite or powder tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with sticks lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the sticks before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.



One type of thawer on the market.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Two of the most frequent causes of accidents while thawing explosives are in putting the sticks into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the sticks. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When sticks of explosives are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock.

Causes of Accidental Explosions

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a *DRY* warmth. Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Safe Thawing

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the sticks of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold

sticks of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.

Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the sticks inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the sticks of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

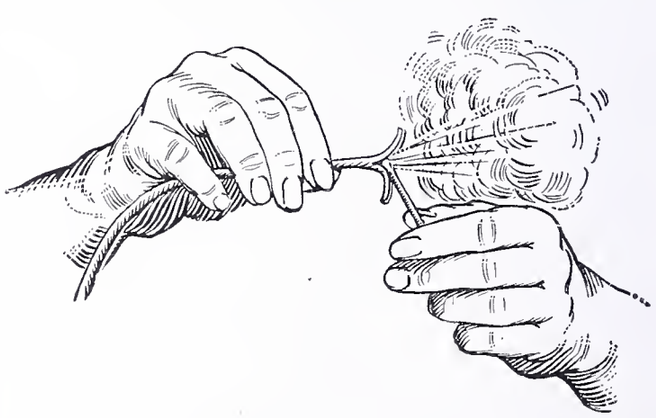
The old-fashioned manure pile method of thawing is reliable and safe, though a good deal of trouble. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite or powder in this way. Twenty hours is better.

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the sticks to see if the freezing and thawing causes the sticks to leak free nitroglycerin. If any of this leaks out of the stick and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 61 and 62.) The sticks of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Sticks on Sides

Electric and Fuse Firing

The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.



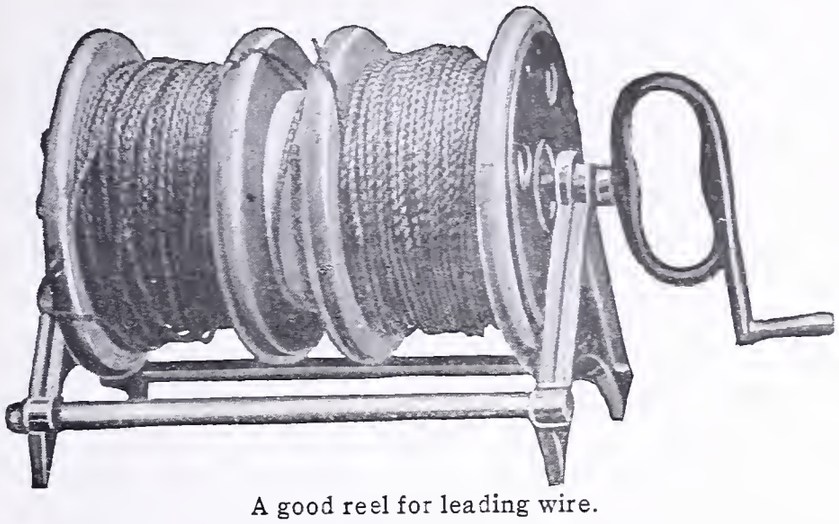
Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further discussion of fuse firing, except as to its adaptations, is not needed.

Fuse and Cap Firing

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, will not need any other method of firing than by caps and fuse. Ditch blasting in ground not watersoaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small

Electric Firing

boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.



A good reel for leading wire.

Advantages

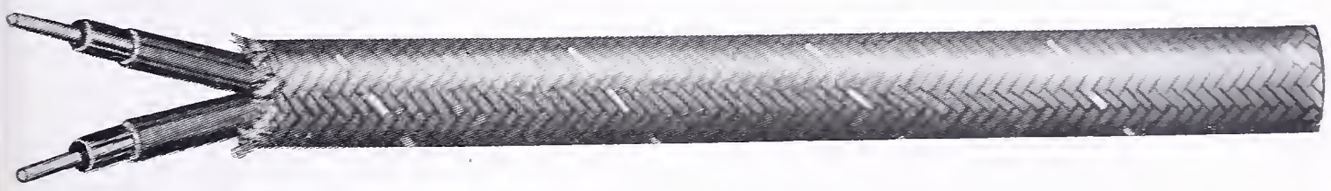
The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching, you can fire many charges in a row and make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

Electric Machine

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a modified magneto with a handle on top that you either push down or pull up, depending on the make of machine, to operate and to fire the charges. The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 10 pounds. Full directions for operating and caring for the machines always accompany them.

For electric firing, in addition to the machine, you will need electric blasting caps, connecting wire and leading wire. The leading wire is copper wire large



Duplex Leading Wire. (Actual size.)

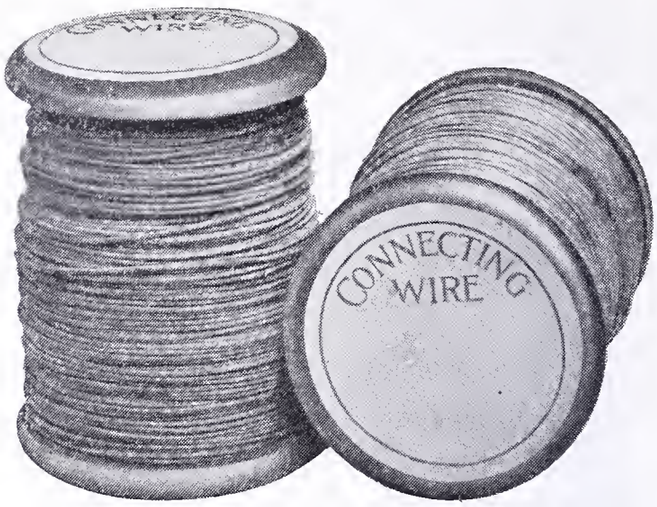
Wiring

enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use. To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the

explosive makers in single-strand form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

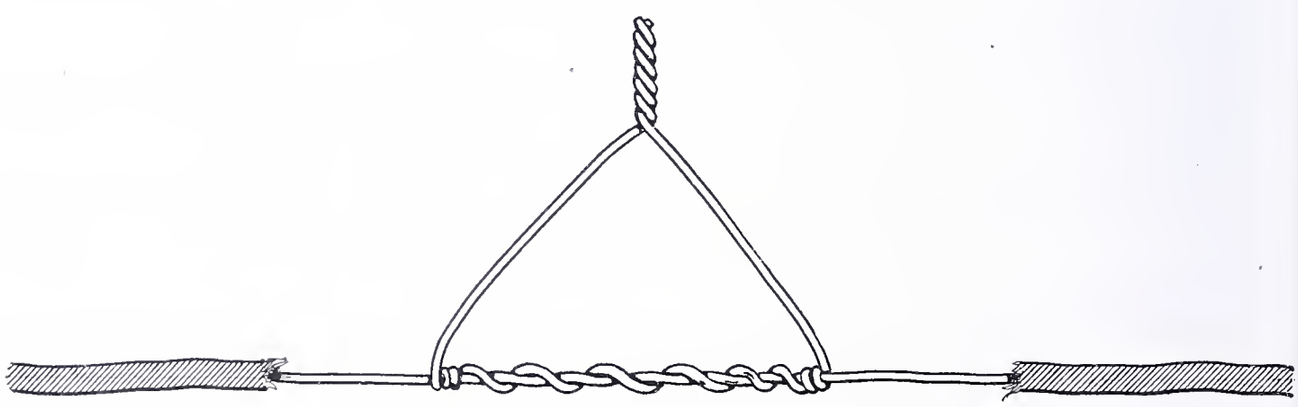
The two small copper wires that are fixed in the electric blasting caps (see page 59) should be long enough to reach out of the holes. They may be bought in a variety of lengths, but 4 or 6 feet are regarded as standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together, up to 25 feet or more.

Electric Blasting Caps

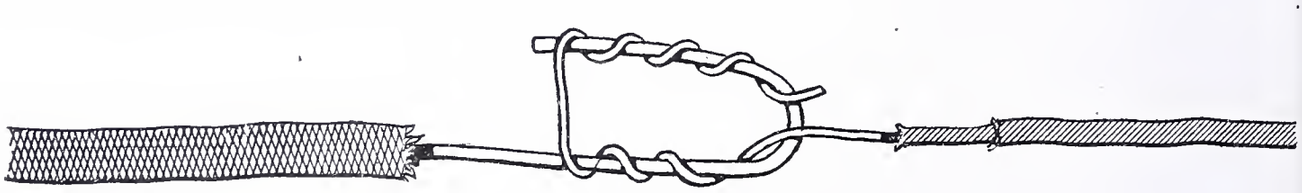


Connecting wire comes on spools.

A very bad connection—a cause of misfires.



Good connection for electric cap wires.



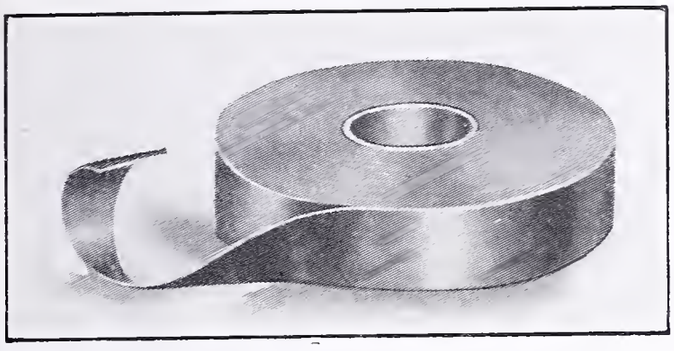
Good connection for small cap wires and large leading wire.

The diagrams in these pages will show how to make electric wire connections. Cut away the insulating on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires.

Wire Connections

If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to

insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.



Tape for wrapping joints and broken insulating.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure that the charges are all ready and after every person and animal is out of the way of the flying pieces.

When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.

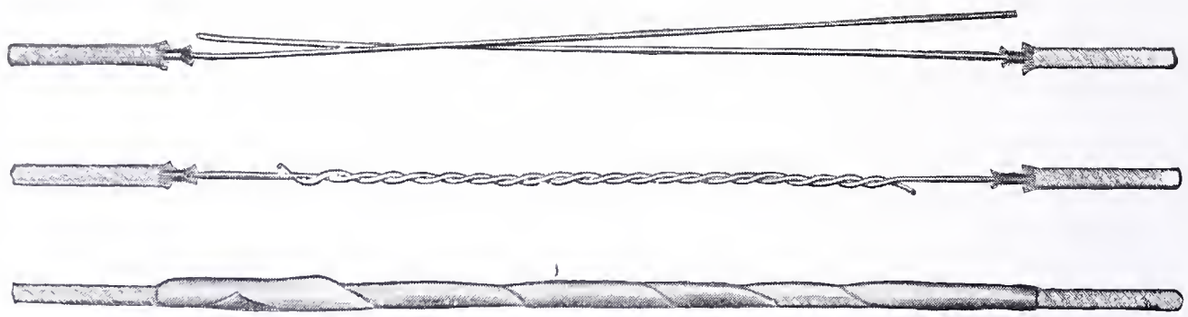
Very best wire connection, ready for soldering if need be. (Excellent for leading wire.)

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 57.)

Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charge. Do not use this method where it involves many splices with connecting wire.

Connections in parallel sometimes are desirable in the case of ditches, or other extensive blasting. To make them run a piece of wire away from one leading wire strand along the lines of charges and connect one wire to each charge. Then run another similar piece of connecting wire connected to the other strand of leading wire, and attach to it the other cap wire of each charge.

But to fire charges by means of parallel connections takes so much electric current that a blasting machine cannot be used. Generally speaking, parallel



Method of wrapping wires together to make electrical joint, and of taping joint.

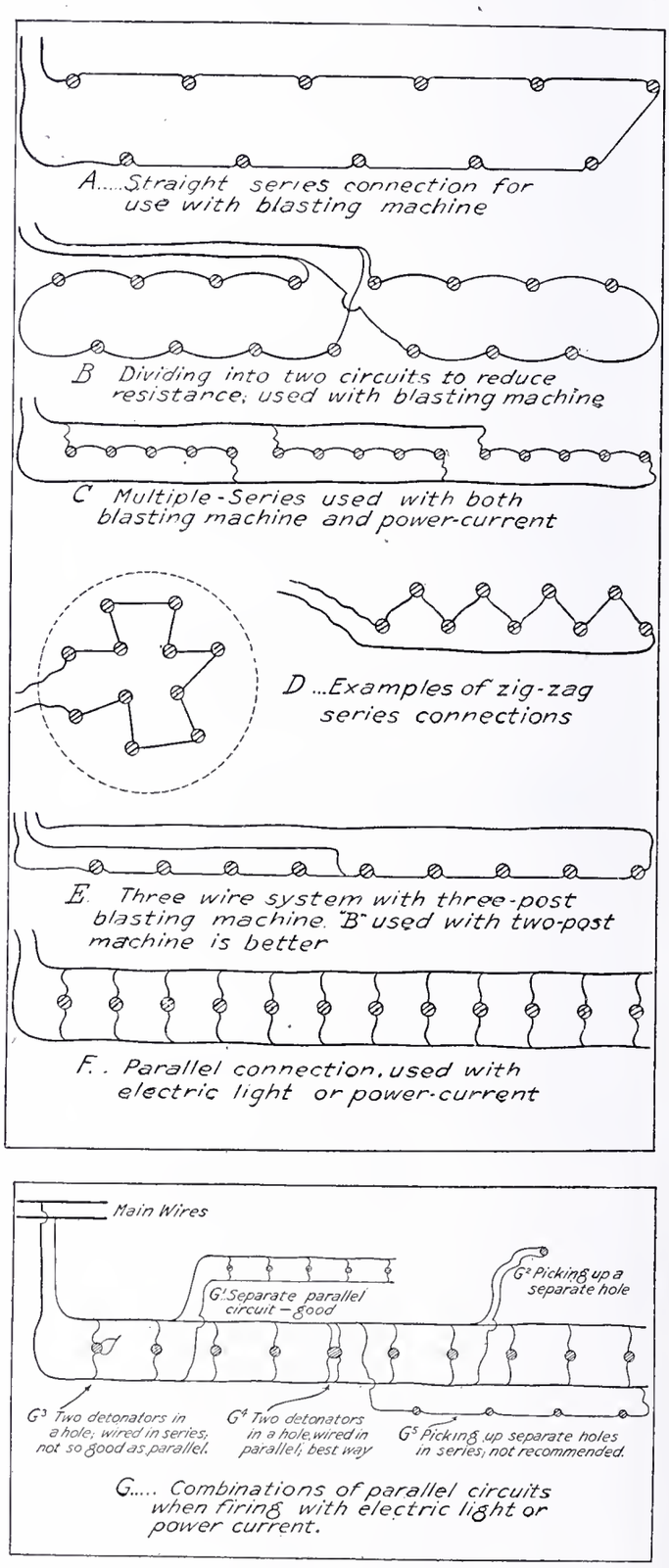
connections require current from an electric light or power plant. If your work is such that the charges cannot be connected in series or that parallel connections are desirable, it is well to communicate with an expert or authority on electricity for special suggestions and advice as to how best to fire your charges.

Current Required

In a bulletin of this size it is impossible to give a comprehensive statement of electric firing. But to give some idea, it can be stated that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.

When charges are connected in parallel, instead of series, or in multiple series (see diagram C), each circuit requires 1 to 1½ amperes of current. That is, each cap requires 1 to 1½ amperes when connected in parallel. The voltage required, of course, depends on the resistance of the wires. A very much greater current than of 1 to 1½ amperes will do no harm; in fact it is desirable.

Electric blasting machines are constructed to give a sufficient amperage and voltage for



Ways of connecting up charges for electric firing.

firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes will do the same, or it may do nothing. In emergencies dry cells or wet batteries can be used by skillful operators to fire a few charges, when great care is taken to have the wiring arranged for the purpose. Before attempting to fire charges with batteries of any kind, learn the amperage and voltage of their output and see that your shots come within their limits. The use of batteries is more expensive than the use of electric blasting machines.

Two post electric blasting machine—push down type.

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulating of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is watersoaked or that is covered with mud will lose a considerable part of its current.

Misfires

Nearly half of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 60.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot with entire safety as soon as the lead wire is disconnected from the blasting machine.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine, cap pulled out of explosive, bad wire connection at some point, or broken wire.

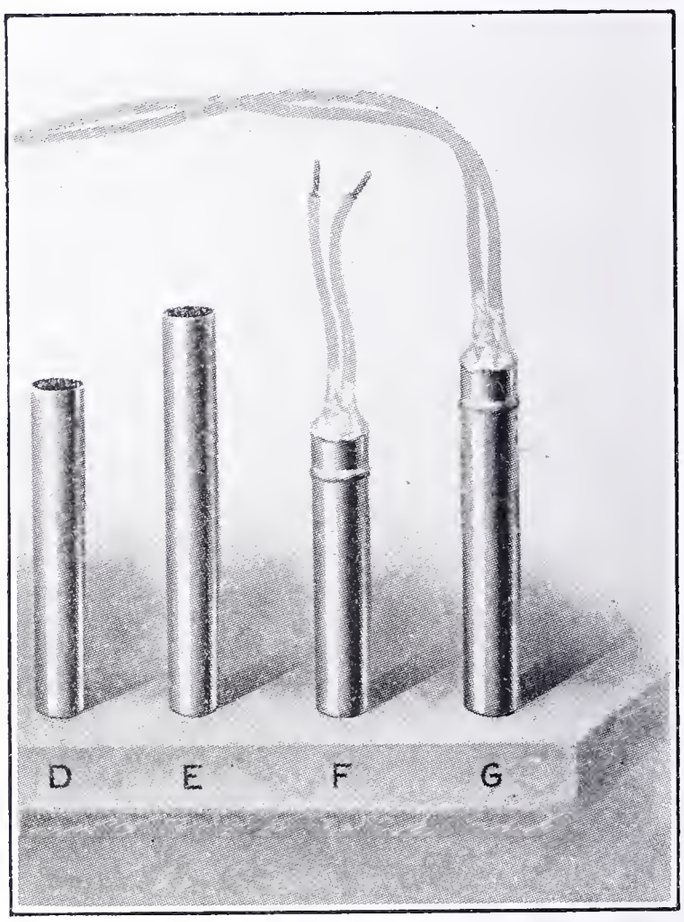
If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches of the original one. The explosion of the new charge will explode

the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

Cap (Detonators)

Blasting caps are little copper tubes closed at one end, 1½ to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.



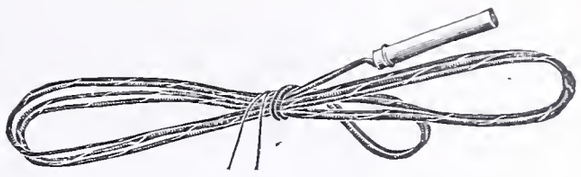
D and E are ordinary blasting caps; F and G are electric blasting caps, often called fuzes.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite or powder to be fired. If it were not for safety in handling blasting explosives, they all could be made as sensitive as the material in the caps. But such explosives would be impossible to handle without accident. In fact, it would be impossible to handle the little bit of explosive in the caps if it was not protected by the copper shells. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

The strength of caps is carefully regulated by the makers to fire the dynamites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.

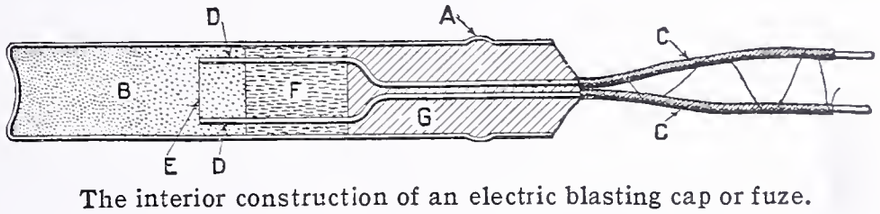
Blasting caps must be used with fuse. And before they are inserted in the stick of explosive they must be fixed to the fuse properly. (See pages 37 to 40.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.



Electric blasting cap or fuze.

Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.

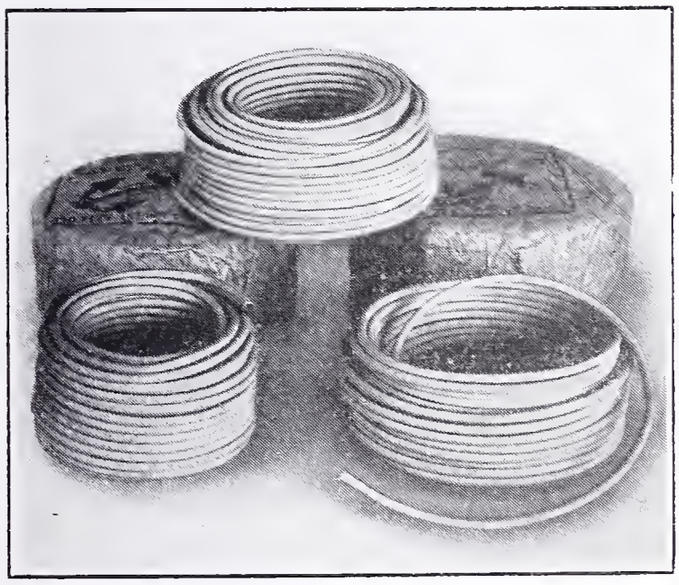


The interior construction of an electric blasting cap or fuze.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

Fuse (Safety Fuse)

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.



Fuse as it comes in rolls.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.

Grades

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton

covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a waterproof grade, since it can be used for both wet and dry work.

Most reliable fuse burns about 2 feet per minute when in perfect condition. If it becomes damp, it burns much slower. Cases have been known where the spark smouldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

Rate of Burning

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites and powders in boxes can be hauled freely in spring wagons. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tieing them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the sticks of explosive in their original boxes until you are ready to use them. Don't have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay sticks or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat sticks of dynamite, or powder, because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the sticks. For this same reason some people punch holes for caps in the sticks with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. *Keep them safe from any jars or heat.* You can sometimes do

Handling

many foolish things with dynamite and powder without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites and powders on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosive must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 48, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Magazines

Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.

Blasting caps of any kind must not be stored with dynamite or powder. Fuse is not explosive and can be stored with dynamite or powder.

Caps

Blasting caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the sticks, or may even cause it to leak out of the wrappings through the boxes and to the floor.

Deterioration

Strict watch should be kept of the sticks and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the sticks feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them much. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the stick wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

Shipping Explosives

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than $2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, Underwood Building, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers

for hire, and that no explosives under deceptive or false markings or understanding shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight, the same as groceries or dry goods. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, *and that shipments must be removed from the receiving station within 24 hours of their arrival there.* The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the *safety* of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen sticks of dynamite or powder. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen stick of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the stick in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the stick is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out

and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be entirely safe to handle.

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